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THE CHARACTERS OF THE ENGLISH THIGH-BONE. PART II.: THE DIFFICULTY OF SEXING.

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ON p. 238 of the 48th volume of the *Journal of Anatomy* I published a paper on "The Characters of the English Thigh-Bone," founded on the detailed examination of some 300 femurs from the great collection of bones beneath the church at Rothwell in Northamptonshire.

These bones, we have every reason to believe (see *Jour. R. Anthrop. Inst.*, vol. xl., 1910, p. 483), belonged to inhabitants of that town who died in the thirteenth, fourteenth, and fifteenth centuries, and I hoped, and still hope, that they may form a standard with which to compare other collections of thigh-bones.

As Dr Wood Jones accurately observed, in the discussion which followed the paper, a distinct though unavoidable source of weakness was the fact that the bones had been arbitrarily sexed by myself from previous experience gained in London dissecting rooms and museums, and it was too much to hope that in every case I had judged rightly.

For this reason it seemed necessary to examine a series of modern femurs, the sex and age of which were definitely known, in order

(1) To see whether a group of sexual characteristics could be established.
(2) To test these in order to prove how far they are reliable.
(3) Having defined and tested the sexual characters, and having discovered my powers of accurate sexing, to review the sex of the Rothwell bones by their aid.
(4) To compare the readjusted average measurements of the Rothwell bones with those of modern London dissecting-room subjects.

Unfortunately, the only femurs I could use for my comparison were those of our dissecting rooms, and they are open to three objections:

TABLE I.—MALE FEMURS FROM LONDON DISSECTING ROOMS.

No.	Height.	Age.	Maxl. Length.		Obl. Length.		Diam. of Head.		Width. Lower End.		Shaft. L. Diam.		Platymeria. Ant. Post.		Platymeria. Transverse.		Platymeria. Index.		Angle of Neck.		Length of Neck.	
			R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.
1	172·2	69	470	473	462	466	50	51	79	80	28	28	29	29	36	33	81	88	...	...	...	...
2	183·0	34	480	480	472	478	50	50	80	80	25	26	28	30	35	35	80	86	...	...	...	...
3	165·1	71	433	...	431	...	48	...	79	78	29	27	29	29	34	34	85	85	...	...	...	...
4	165·1	82	450	450	445	450	48	48	...	...	28	29	30	28	31	34	97	82	...	...	...	...
5	175 3	73	468	463	460	458	50	50	...	...	27	28	31	28	31	32	87	87	...	...	...	...
6	167·7	81	475	472	472	470	50	51	...	...	28	29	33	32	35	35	94	91	...	...	. .	...
7	162·7	58	442	445	440	442	48	49	80	80	29	30	30	28	32	32	94	87	...	...	...	...
8	149·2	64	391	395	388	389	44	46	68	70	27	26	26	28	31	33	84	85	119	117	57	60
9	159·5	60	...	423	420	420	49	49	81	80	28	29	28	29	33	34	85	85	125	120	65	64
10	183·5	47	511	500	509	497	52	51	79	79	30	29	27	26	37	37	73	70	125	120	81	76
11	171·5	79	468	...	467	...	52	...	82	...	31	...	30	...	38	...	80	...	118	...	70	...
12	161·4	68	435	432	433	430	49	49	80	80	27	27	26	...	34	...	77	...	114	...	69	...
13	169·0	80	486	489	481	485	51	51	81	81	29	30	29	30	36	33	81	91	...	...	...	...
14	162·7	78	447	445	444	441	47	47	72	72	27	27	30	29	31	31	97	94	130	128	57	57
15	174·0	62	474	475	471	473	50	51	87	87	30	31	29	28	37	39	78	72	120	124	68	72
16	176·6	71	473	474	471	468	53	52	81	81	30	30	28	29	34	35	82	83	117	118	72	73
17	172·2	61	459	459	456	455	51	51	83	82	31	31	32	31	33	35	97	89	121	119	66	67
18	162·7	58	442	445	440	442	48	49	80	80	29	30	30	28	32	32	94	87	122	122	68	67
19	155·6	49	426	414	424	414	46	45	70	70	28	29	31	31	36	36	86	86	118	118	66	65
20	156·8	68	426	...	426	...	51	...	80	...	29	...	28	...	36	...	78	...	130	...	70	...
21	172·8	80	465	455	460	453	53	52	86	85	29	...	31	31	33	35	94	89	130	123	68	72
22	163·8	61	444	..	440	...	49	49	76	76	24	25	29	28	34	36	85	78	126	125	66	65
23	177·8	21	485	485	483	484	51	51	80	80	27	26	29	29	33	34	88	85	124	122	67	67
24	161·4	64	...	413	...	410	...	45	...	77	...	27	...	30	...	33	...	91	...	114	...	65
25	184·2	63	507	507	504	503	52	51	83	83	27	28	28	29	32	33	87	88	...	129	66	64
26	160·0	50	428	423	426	420	46	44	75	74	28	28	28	27	35	35	80	77	...	...	65	57
27	175·3	70	477	473	475	469	52	52	80	81	31	33	32	32	40	41	80	78	...	...	75	72
28	163·8	78	437	449	432	445	51	52	78	78	26	27	27	28	34	35	79	80	...	...	66	67
29	167·7	53	461	463	458	460	49	49	76	77	27	27	29	28	30	31	97	90	...	...	58	60
30	160·7	73	435	440	430	438	47	47	79	77	30	30	29	31	35	36	83	86	118	113	65	64
31	162·0	66	429	...	426	...	48	...	75	...	27	...	27	...	33	...	82	...	130	...	64	...
	167·6	64	456	455	452	452	49·5	49	79	79	28	28	29	29	34	34	85·5	85	123	121	67	66

firstly, that their possessors were for the most part aged people (their average age was 64); secondly, that they were the derelicts of the London poor, coming as they did in nearly equal proportions from the Poor Law Infirmaries and Pauper Lunatic Asylums; thirdly, that the number of bones which could be preserved intact for measuring was necessarily limited, and, as far as the females go, probably not numerous enough to give very reliable statistics.

An examination of the accompanying tables will show that my data consist of measurements of 31 male and 14 female subjects, taken in the dissecting rooms of St Thomas's and Guy's Hospitals. The average height of the males was 5 feet 6 inches and of the females 5 feet 1 inch, and I first propose to consider how far the advanced age of my material is likely to affect any general conclusions drawn from it.

It is clear that the age changes in the femur will chiefly affect the proportion which it bears to the stature.

If the average maximal length of all the male femurs be taken and 3 mm. deducted for the cartilage, because they were examined in the recent state, the result is 453 mm.; and Pearson's formula (*Phil. Trans.*, vol. cxcii. p. 244), which was founded on observations of people who had died before senile changes began, gives a stature of 167 cm. as corresponding to this length. As the actual stature of the men from whom the present femurs were taken averaged 5 feet 6 inches, or 167·6 cm., it does not look as if there were any serious error as far as the males are concerned.

With the females, on the other hand, there is 4 cm. wanting in actual stature when compared with the stature to which their femurs entitle them under Pearson's formula, and for this reason and their small number I am quite ready to agree that the results obtained from them are not likely to be as satisfactory as are those obtained from the men.

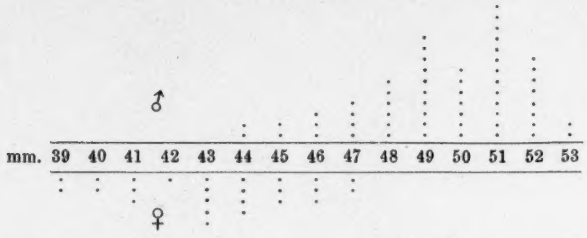
The Selection of Sexual Tests.

My next attempt will be to select a certain number of measurements which seem either beyond the overlap of the range of variation in the two sexes, or are at least so near the margin as shall make it extremely likely that the right sex is indicated.

Taking the vertical diameter of the head of the femur, it will be noticed that in the tables there are 82 records (57♂ and 25♀), and the mean between the average of the two sexes is 46 mm. with the cartilage in position. If we were to take this 46 as the border line on which the sex could not be told, and all cases above 46 as male, and all below as female, we should be right 70 times (85 per cent.), wrong 6 times (7 per cent.),

while 6 cases (8 per cent.) would fall on the border line and therefore could not be determined.

TABLE II.—DIAMETERS OF MALE AND FEMALE FEMUR HEADS.



If we look at the accompanying curve (Table II.), it will be evident that a certain proportion of male femur heads are less than 46 mm., and a certain small proportion of females more than 46. In this small series no females were over 47; but Dwight, who published a series of 200 measurements of each sex,[1] shows that in American women of white ancestry 48, and even as much as 51, may rarely occur, while on the other side the male bone may sink as low as 42. I do not propose to notice these extreme cases, but I think that for practical purposes all English femurs the heads of which, with the cartilage on, measure between 44 and 48 mm. inclusive, should be submitted to further scrutiny.

I have satisfied myself that, when the blades of the calipers are held parallel to the long axis of the neck, as in fig. 1, the cartilage occupies more than 1, but less than 2, mm. A subtraction of 1 mm. for absence of cartilage seems, on the whole, to give the fairest results. The figure also indicates how easily the measurements may be affected by tilting the blades of the calipers.

Having decided that all English femurs with heads above 48 mm. may be put on one side as males, and all with heads of less than 44 mm. as females, to what further tests shall the intermediate bones be submitted?

The Length-head Index.—It is constantly stated that the head of the female femur is not only actually smaller than that of the male, but smaller relatively to the length of the femur.

In order to test this, I divided the maximal lengths of all the male and female femurs into the vertical diameter of the head. In the males I found that the average index thus obtained was 109, while in the females it was 104. This appeared at first a hopeful clue to the sex, but I soon found

[1] *American Journ. of Anat.*, vol. iv. No. 1, pp. 19–31.

that there was such an overlap in the range of variation that it was only useful when very strongly marked.

The male range of variation I found was 102–120, while the female was 83–114.

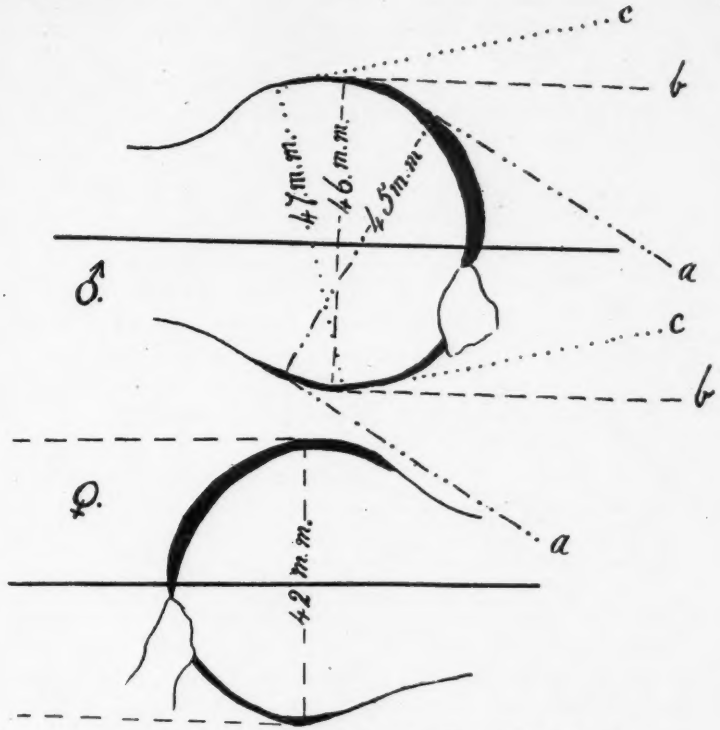
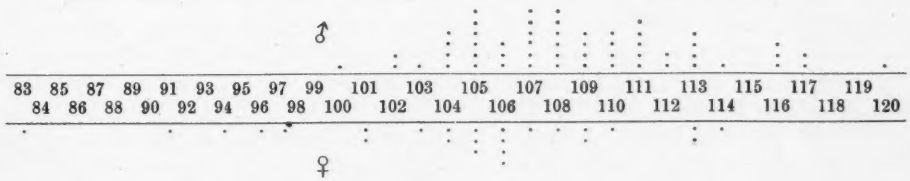


FIG. 1.—Sections of femur heads to show how the position of the calipers affects the measurements.

TABLE III.—INDEX OF FEMUR HEAD TO FEMUR LENGTH: COMPARISON IN THE TWO SEXES.



It is clear from the accompanying table that indices between 104 and 109 would give little help in sexing, but the chances of a bone with an index over 109 being male, and one under 104 being female, are very great. I admit, however, that the number of female observations is not large enough to justify anything more than a tentative suggestion, and the test is one upon which too much value should not be placed except in extremely marked cases.

The Width of the Lower End.—If the upper extremity is of great value in sexing, it is possible that the width of the lower end may afford a clue in those cases in which the head is not conclusive.

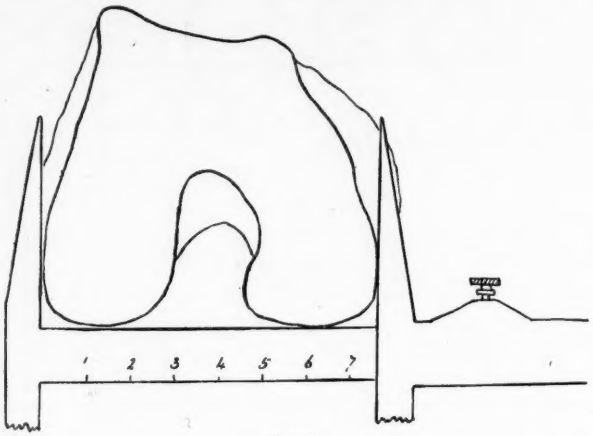


FIG. 2.

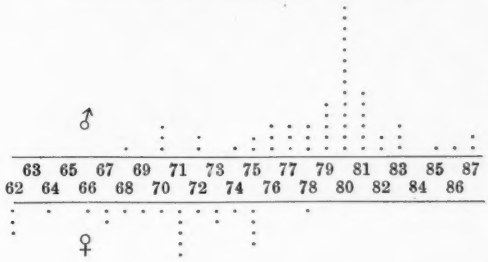
Fig. 2 shows the method of taking the width, and has been reproduced from my former paper on the Rothwell bones. The average breadth for male bones is 79 mm., and for females 69 mm. This is with the cartilage and periosteum in position, but I find that when dry bones are measured 2 mm. should be allowed for these.

From this chart it appears that any measurement between 70 and 75 mm. (inclusive), although probably female, would be very unreliable. Measurements over 75 would seem to be almost certainly male, and those under 70 equally certainly female, though the chance of these being helpful is not as great as one would like, because the bones which have indefinite heads have also very often indefinite lower ends.

To illustrate this, one may notice that there are among our records 28 cases in which the head is between 44 and 48 mm. inclusive. These,

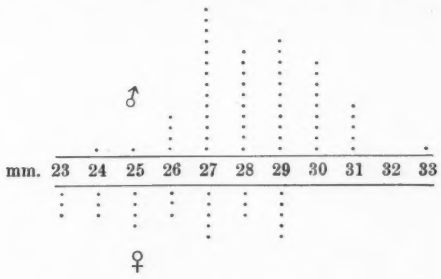
therefore, are of doubtful sex, and in only 5 of them did the lower end accurately indicate the sex. In 2 the measurement of the lower end was unobtainable, in 2 it was absolutely misleading, while in 19 it varied between 70 and 75, the indefinite region.

TABLE IV.—CHART OF LOWER END WIDTHS.



The Least Transverse Diameter of the Shaft.—This I think is an important measurement, because it is not only of some little use for sexing purposes, but it affords a useful clue to the robustness of the skeleton.

TABLE V.—CHART OF THE TRANSVERSE DIAMETER OF THE SHAFT IN THE TWO SEXES.



The average male measurement is 28 mm. and the female 26 mm., but it is evident that between 25 and 29 the overlap of the variation of the sexes is so great that it will only be safe to presume that anything under 25 is probably female and over 29 male.

Platymeria.—The amount of platymeria is not usually a point which we expect to help us in determining sex, but we are gradually accumulating information on this interesting condition, and it will be well to see whether these London bones can help us.

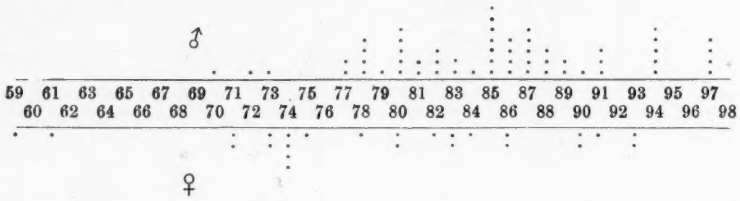
A few years ago we regarded platymeria as a characteristic of certain uncivilised or partly civilised races, and it was thought to be the result of the action of muscles used in hill climbing. Lately it has been found quite well marked among Bronze Age and Saxon dwellers in the British Isles, while still more lately I have been able to show that among the mediæval inhabitants of Rothwell over 11 per cent. of the males and 27 per cent. of the females had femurs, the platymeric index of which was below 75: and an index of 75 means that the bone is strikingly platymeric to the eye, unaided by any measurements.

I therefore came to the conclusion that at Rothwell platymeria, contrary to Manouvrier's experience, is a good deal commoner in women than in men.

In the 31 modern English males with which I am now dealing the average index is 85·5 on the right and 85 on the left, only two individuals showing an index of less than 75.

In the 13 females the average index is 80 on the right and 79 on the left, but the interesting point is that 6 out of the 13 (46 per cent.) had an index of less than 75 on one or both sides.

Table VI.—Chart of the Platymeric Indices in the Two Sexes.



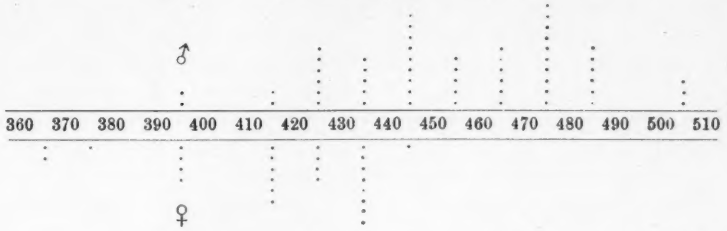
The above chart suggests that very high indices are probably male, and very low probably female. Anything between 75 and 90, however, would appear too uncertain to trust.

The Maximal Length.—This, of course, must not be taken too seriously as an indication of sex, nor, on the other hand, can we afford to ignore it.

There is no doubt that a short femur should suggest a female bone other things being equal, though the amount of sexual difference probably varies in different races and under different conditions of culture. Among the English middle and lower classes of to-day I believe that the difference in height between the sexes is appreciably greater than it was among the Anglo-Saxons.

From the accompanying chart it would appear that a femur length of over 450 mm. or even 440 is strongly in favour of the male sex, while one under 400 is probably female.

TABLE VII.—MAXIMAL LENGTHS IN THE TWO SEXES.



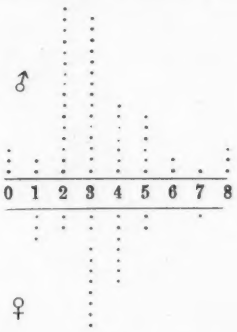
Difference between Maximal and Oblique Lengths.—Professor Elliot Smith found that among ancient Egyptians the most satisfactory test of the sex of the thigh-bone was the much greater difference between the maximal and oblique lengths in the female than in the male, and this he ascribed to the greater obliquity in the female.

I do not think that this applies to English people, for at Rothwell I found that the obliquity of the female bone was, on an average, only one degree more than that of the male. However, as the sexing of the Rothwell bones is partly the subject of this inquiry, I must confine my observations for the present to these London femurs, the sex of which I really do know.

In the males the average difference is 3·4 mm. on the right side, 3·2 on the left. In the females, 3·5 mm. on the right, 3·0 on the left.

As the point is evidently an important one in a negative way, the accompanying chart will show the range of variation in the differences.

TABLE VIII.—CHART OF DIFFERENCE BETWEEN MAXIMAL AND OBLIQUE LENGTHS.



The Length-thickness Index.—This will be a convenient place to mention another negative result. I had hoped that the ratio between the

length and least diameter of the shaft might give a clue which would be valuable in those cases in which the head-length index proved valueless. After working out all the indices, I found that the overlap of the variations in the two sexes was so enormous that the work was valueless, and I only mention it to save others from a like disappointment. It will now be as well to recapitulate the tests on which I propose to depend for sexing English femurs.

1. Femur heads with a vertical diameter of over 48 mm. are males, under 44, females. In dry bones without cartilage 1 mm. should be subtracted.

In bones between 44 and 48 mm. one or more of the following tests may be available:—

2. Length-head index . . . −104 ♀ +109 ♂.
3. Width of lower end . . . −70 mm. ♀ +75 ♂.
   (2 mm. should be taken off where there is no cartilage or periosteum).
4. Least transverse width of shaft −25 mm. ♀ +29 ♂.
5. Platymeric index . . . . −75 ♀ +90 ♂.
6. Maximal length . . . . −400 mm. ♀ +450 ♂.

Having done this, I will deal with the 82 femurs obtained from the London bodies as if they were brought me with their labels removed and with only a reference number attached by which the sex might be looked up, and I will see how far the tests which I have just recapitulated will enable me to sex them accurately.

In the first place, 53 of the 82 (65 per cent.) have heads which are either over 48 or under 44 mm. It is the other 29, with heads between and including these numbers, with which we are particularly interested, and it may help in their consideration if they are picked out and their various crucial measurements placed beside them.

No.	A. Maxl. Length.	B. Head.	C. Head-length Index.	D. Width of Lower End.	E. Tr. Width of Shaft.	F. Platymeric Index.	No. in List.
1	433	48	111	79	29	85	3 ♂. R.
2	450	48	107	...	28	97	4 ,,
3	442	48	109	80	29	94	7 ,,
4	391	44	113	68	27	84	8 ,,
5	447	47	105	72	27	97	14 ,,
6	442	48	109	80	29	94	18 ,,
7	426	46	108	70	28	86	19 ,,
8	428	46	108	75	28	80	26 ,,
9	435	47	108	79	30	83	30 ,,
10	429	48	112	75	27	82	31 ,,

No.	A. Maxl. Length.	B. Head.	C. Head-length Index.	D. Width of Lower End.	E. Tr. Width of Shaft.	F. Platymeric Index.	No. in List.
11	450	48	107	...	29	82	4 ♂. L.
12	395	46	116	70	26	85	8 ,,
13	445	47	106	72	27	94	14 ,,
14	414	45	109	70	29	86	19 ,,
15	413	45	109	77	27	91	24 ,,
16	423	44	104	74	28	77	26 ,,
17	440	47	107	77	28	86	30 ,,
18	434	44	101	71	28	90	1 ♀. R.
19	396	45	114	70	26	71	2 ,,
20	429	47	110	78	26	80	6 ,,
21	426	45	106	73	26	78	7 ,,
22	437	46	105	71	27	80	8 ,,
23	420	44	105	74	25	84	9 ,,
24	436	44	101	71	29	93	1 ♀. L.
25	430	47	109	75	29	74	6 ,,
26	426	45	106	73	27	78	7 ,,
27	434	46	106	71	29	82	8 ,,
28	422	46	109	75	29	59	10 ,,
29	417	45	108	72	28	91	14 ,,

No. 1 is a male bone by tests C and D; it has no female characteristics.

„ 2. A, F, and B all suggest male; nothing female.

„ 3. B, C, D, E, and F point to male; nothing female.

„ 4. A, B, D suggest female. The only male point is the head-length index of 113. C. I fear that I should have made this female.

„ 5. Everything indefinite except F, which points strongly to a male.

„ 6. B, C, D, and F point to male; nothing definitely female.

„ 7. Every characteristic is negative, but I fear that the small lower end would have inclined me to a female decision.

„ 8. C, D, and E approach the male border-line, and there is no similar approach to the female anywhere.

„ 9. D and E are definitely male.

„ 10. B and C are definitely male.

„ 11. Nothing is definite, but all measurements lean to the male side.

„ 12. C strongly male; others indefinite, except A, which would be female were it not so strongly overpowered by C as to make one almost sure that a small man is being dealt with.

„ 13. F definitely male, others indefinite.

No. 14. C is just on the male line, and so is E. Similarly, B and D are near the female line. Using F, therefore, as the decisive factor, it is found fairly close to the male limit, and so I think the bone should be regarded as that of a small male.

„ 15. D and F are distinctly male, while C is on the male border-line.

„ 16. B and F are distinctly female, and there are no distinctly male characteristics.

„ 17. D and F are distinctly male.

So far these bones were all really male, and of them 3 (Nos. 4, 7, 16) appear to be female by the use of my tests.

The other 14 appear to be male.

No. 18. B and C are distinctly female; D is on the female and F on the male border-line.

„ 19. A, B, D, and F point to the female sex, though C is distinctly male. The balance is certainly female.

„ 20. C and D are distinctly male, and there is nothing characteristically female about the bone.

„ 21. C and E are close to the female border, and so is F. Though there is nothing definitely pointing to either sex, the trend of these three measurements should, I think, be sufficient to turn the scale to the female side.

„ 22. C and D are comparatively female, and F approaches the female limit. There are no male features.

„ 23. B, C, and E are markedly female. D alone suggests a male, but it would need strong male evidence to upset B and C.

„ 24. B is presumably female, and so is D. C is definitely female, while E is presumably and F definitely male. On the whole the balance is towards the female sex.

„ 25. B, C, D, and E suggest a male. Only F is markedly female, but I should certainly have regarded this as a male bone.

„ 26. This is a very indefinite bone, though it seems to lean to the female border on most counts.

„ 27. C and D are close to the female border. E, however, approaches the male. On balance it should be female.

„ 28. C, D, and E are all on the male border-line of the neutral zone, while F alone strongly suggests a female. In spite of this extreme platymeria I should have made the bone male.

„ 29. C, E, and F suggest a male. A suggests a female, but would not have counterbalanced the others in my opinion.

Of these 12 really female, though apparently doubtful, bones, therefore, 4 (Nos. 20, 25, 28, and 29) have been wrongly sexed and 8 rightly.

The net result of my endeavours is that, of the 82 femurs, 53 (65 per cent.) were at once settled correctly by the very large or very small size of their heads; while of the 29 which were regarded as doubtful, 22 were accurately and 7 inaccurately sexed. I have therefore made seven mistakes in 82 bones, or 8·5 per cent. failures and 91·5 per cent. successful attempts.

It was shown on p. 347 that, by merely taking the head diameters, 70 of the 82 bones could be accurately sexed, and that only six instead of my present seven mistakes were made; but then six bones were left on the border-line, with a head measurement of 46, and in order to make the two methods comparable I should be allowed to set aside the six most puzzling cases, which would no doubt have reduced my mistakes considerably. Of course I realise that no anatomist would allow himself to depend entirely on the head measurement in sexing femurs; he would use the general impression which his trained eye would provide to supplement or correct the evidence of the calipers. This experience is, however, a most uncertain asset, and must vary a good deal in different individuals. Without practical tests which might lead to misunderstandings it is almost impossible to estimate the value of any particular individual's sexing of femurs, skulls, or other bones, and so I think that a comparatively hard-and-fast method, giving a known error of some 8 or 9 per cent. and independent of the personal element, will prove an advantage, in spite of its greater laboriousness, if mathematical deductions are to be made from femurs the sex of which cannot be absolutely known.

Having chosen a series of sex tests for femurs and having gained some idea of their value, I now propose to reconsider my sexing of the femurs at Rothwell. In sexing these bones I was not entirely dependent on the head measurements, but took the general appearance into account, being guided in my final decision by a comparatively loose and ill-defined experience.

Now that I have reduced my experience to definite figures, I can see that there are some of the Rothwell bones which I should have sexed differently.

There are 10 femurs among the 185 males which I now believe to be females, and 4 among the 108 females which I now think males. At the cost of a good deal of labour I have rearranged these bones, and, after calculating the averages once more, find that there is no great change in the result printed on pp. 244–251 of my former paper in the *Journ. of Anat. and Physiol.*, vol. xlviii.

The following table shows how small an effect a transference of some 5 per cent. from one sex to the other makes in the average result:—

		Oblique Length.	Maxl. Length.	Head Diamr.	Width of Shaft.	Width of Lower Extremity.	Platymeric Index.
R. ♂	Before transfer . .	453	456	49	29	77	77
	After ,, . .	452	455	49	29	77	78
L. ♂	Before ,, . .	456	460	49	30	77	81
	After ,, . .	457	460	49	30	77	83
R. ♀	Before ,, . .	415	416	43	26	68	78
	After ,, . .	417	420	43	26	68	77
L. ♀	Before ,, . .	418	422	42	27	67	79
	After ,, . .	420	424	42	27	68	76

The chief change is to reduce the difference between the right and left maximal lengths of the female bones by 2 mm., and to increase the difference between the oblique lengths of the male bones on the two sides by a like amount. The platymeric indices of these are reduced below that of the males on either side. Incidentally, the curious want of harmony between the maximal and oblique lengths of the right female bones is smoothed out, and the maximal length gains the normal 3 mm. over the oblique. This, I think, is an indication that the rearrangement is a natural one.

Having resexed the Rothwell bones, and readjusted their averages, it will be interesting to compare them with the modern London bones, although the latter, as has been pointed out already, are not quite typical of the modern London inhabitant. We must remember, too, to make due allowance for the London bones being in the recent state with the cartilage and periosteum present, whereas the mediæval Rothwell bones were perfectly dry.

Comparison of London and Rothwell Bones.

Length.	♂ R.		♂ L.		♀ R.		♀ L.	
	Obl.	Max.	Obl.	Max.	Obl.	Max.	Obl.	Max.
London . .	452	456	452	455	412	415	415	418
Rothwell .	452	455	457	460	417	420	420	424

By this we see that the Rothwell bones were in almost every case longer than the modern London ones, but, as the latter were measured in the recent state, another 3 mm. must be subtracted from them for the articular cartilage and the effects of drying.

If the maximal length average is taken with this deduction from the London bones we get the following statures:—

	Male.		Female.	
	London.	Rothwell.	London.	Rothwell.
Maxl. femur length .	453 mm.	458 mm.	414 mm.	422 mm.
Stature . . .	167·7 cm. (actual)	168 cm. (Pearson)	155 cm. (actual)	160 (Pearson)

From this it will be seen that the London males were practically the same height as those at Rothwell, though the London females were 5 cm. shorter than the Rothwell females.

When we consider that these London paupers and lunatics were the aged derelicts of the town, we have no reason to think that the passage of five centuries has brought any material decrease of stature.

Diameter of Head.—After deducting 1 mm. from the heads of the London femurs for the cartilage, as already determined, the following comparison with Rothwell is possible:—

	♂	♀
London	48 mm.	42 mm.
Rothwell	49 „	42 „

What little difference there is, is thus in favour of Rothwell.

It may be of interest to compare the maximal length-head indices in the two collections, since they have been used as sex tests:—

	♂	♀
London	109 mm.	104 mm.
Rothwell	107 „	101 „

Obviously Rothwell is a little lower in this index than London, and I have taken this into consideration in resexing the former bones.

Least Transverse Diameter of Shaft.

	♂	♀
London	28 mm.	26 mm.
Rothwell	30 „	27 „

This is a valuable index for estimating the robustness of the individual, and the averages show that the Rothwell people had at least better developed thighs than our modern London paupers.

Transverse Width of Lower End.—It has been stated already that a deduction of 2 mm. for cartilage and periosteum is necessary in comparing recent with dried bones. With this allowance the following comparison is obtained:—

	♂	♀
London	77 mm.	68 mm.
Rothwell	77 „	68 „

Platymeria.—The following is a comparison of the platymeric indices. It has been pointed out already that an index of 75 means that a bone is markedly platymeric to the eye.

	♂		♀	
	R.	L.	R.	L.
London . . .	85·5	85 mm.	80	79 mm.
Rothwell . . .	78	83 „	77	76 „

This table shows that the mediæval Rothwell bones were distinctly more platymeric than the modern London ones, and that in both cases platymeria is more pronounced in the female than in the male.

Conclusions.

The conclusions to which I have come must be regarded as tentative and suggestive rather than final, because I know quite well that they may be modified by a larger series, particularly of female bones. Still, experience with other bones makes me believe that the modifications will not be great enough to affect the conclusions seriously.

1. I think that I have suggested a series of sexual tests which will ensure a uniform method of sexing for English bones if other anatomists care to adopt them. No doubt they will need modification when bones of other races are dealt with.

2. The tests should give a fairly steady accuracy of some 91 or 92 per cent. against the varying accuracy of different observers the personal equation of whom is unknown.

3. The use of these measurement tests is, I think, a little more accurate than the judgment by eye of an experienced anatomist, but the difference is not very great; the chance of rightly sexing an individual bone is certainly rather greater, but the averages of a large series are only slightly if at all altered. When, however, experience is not available these tests are more reliable by some 6 per cent. than deciding the sex by the size of the head of the femur.

4. The available evidence suggests that London paupers and lunatics

are of nearly the same stature as mediæval midland Englishmen, though they are not as robustly built.

5. Platymeria, whatever its cause, is commoner in women than in men, and is less marked in London paupers of to-day than in English people of the Middle Ages.

6. Incidentally, I have determined, to the best of my ability, the deductions necessary for comparing dry bones with those in the recent state.

TWO CASES, CONSIDERED FROM THE DEVELOPMENTAL STANDPOINT, IN WHICH THE RIGHT SUBCLAVIAN ARTERY AROSE FROM THE ARCH OF THE AORTA BEYOND THE ORIGIN OF THE LEFT SUBCLAVIAN ARTERY; WITH A NOTE ON THE RELATION OF THE SUBCLAVIAN VEINS TO THE CARDINAL SYSTEM.

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THESE cases, as is well known, are due to the persistence in the adult of the distal portion of the right dorsal aorta of the embryo and the severance of its connexion with the fourth arterial cephalic arch. The part of the

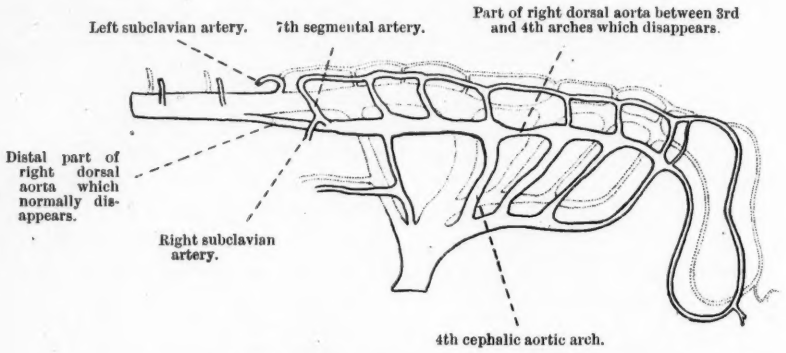
Left subclavian artery.
7th segmental artery.
Part of right dorsal aorta between 3rd and 4th arches which disappears.
Distal part of right dorsal aorta which normally disappears.
Right subclavian artery.
4th cephalic aortic arch.

FIG. 1.—Diagram of the cephalic portion of the arterial system. Modified from Cunningham's *Text-book of Anatomy.*

right dorsal aorta which persists is obviously that which lies between the junction of the right with the left dorsal aorta and the origin of the right 7th dorsal segmental artery (fig. 1). The 4th right cephalic aortic arch and that part of the right dorsal aorta between the origin of the 3rd and 7th somatic segmental arteries disappears, except in those cases

in which the right vertebral artery is given off from the innominate artery.

There is some uncertainty, however, as to whether any part or the whole of the distal portion of the right dorsal aorta is normally represented in the adult by anastomosing vessels joining the subclavian artery with the aorta. It is with the object of clearing up this difficulty that we have turned our attention to the condition of the right dorsal aorta and intercostal arteries in the later stages of embryonic development, and the normal anastomosis of arteries in the adult which takes place across the anterior aspect of the upper thoracic vertebræ and ribs.

Case 1.[1]—The subject in which this abnormality occurred was a male aged 71 years. The right subclavian artery (fig. 2) commenced at the level of the 4th thoracic vertebra from the posterior aspect of the arch of the aorta. It pursued an upward course from left to right behind the trachea and œsophagus to the outer border of the 1st rib. It measured 4 inches in length, and gave off the following branches:—

1st part:—

1. Vertebral.
2. Costo-cervical trunk.
3. Inferior thyreoid.
4. A common trunk dividing into transverse scapular, transverse cervical, and internal mammary.

2nd part:—

None.

3rd part:—

5. Posterior scapular (B.N.A., descending branch of transverse cervical artery).

1. The vertebral artery arose from the upper and posterior aspect of the subclavian, and entered the foramen in the transverse process of the 6th cervical vertebra.

2. The right costo-cervical artery divided into:—

(α) The superior intercostal artery. This vessel supplied the 1st intercostal space, and anastomosed with the 1st right aortic intercostal which supplied the 2nd intercostal space, and with a small branch from the internal mammary.

(β) The deep cervical artery which passed upwards and backwards below instead of above the neck of the 1st rib.

3. The inferior thyreoid artery. This was a large branch which sprang

[1] Dissected by C. P. G. Wakeley.

from the upper border of the main artery. It passed in front of the vertebral artery behind the carotid sheath, and in front of the sympathetic cord.

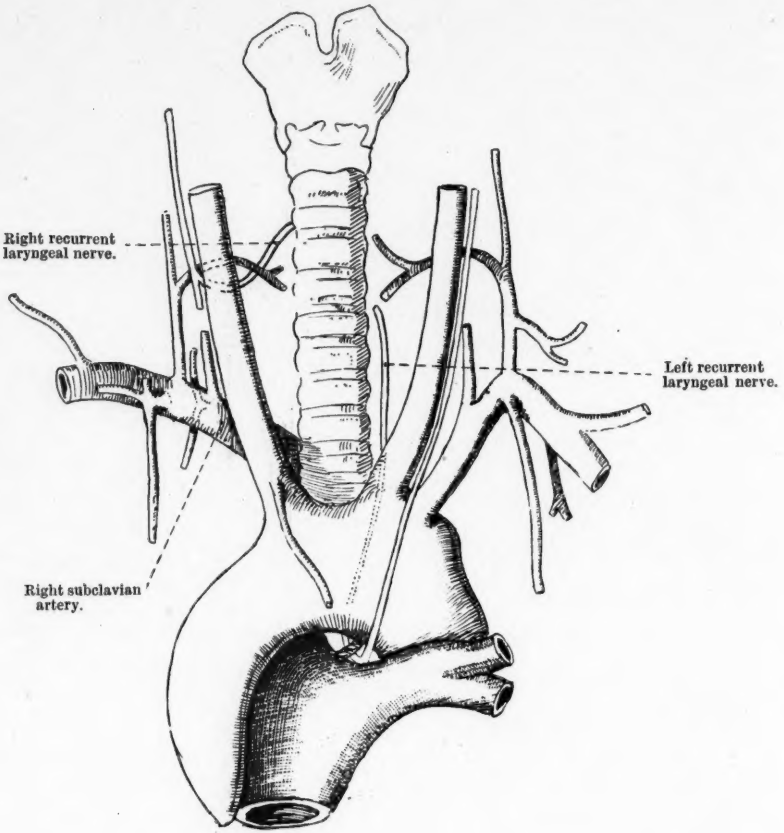

FIG. 2.

4. The common trunk mentioned above was a large branch springing from the anterior aspect of the first part of the subclavian artery. It gave off a lateral trunk which immediately broke up into two branches, the transverse cervical and the transverse scapular. The main artery was continued as the internal mammary.

5. The posterior scapular arose from the upper surface of the subclavian

lateral to the anterior scalene muscle. No "arteria aberrans" was given off from the subclavian artery.

The right common carotid artery arose from the arch of the aorta in front of the trachea and opposite the body of the 3rd thoracic vertebra. It gave off close to its origin a small branch which supplied the thymus gland. The left common carotid and left subclavian arteries arose, close together, from the summit of the aortic arch. The branches given off from the left subclavian were :—

1. Vertebral.
2. Internal mammary.
3. Thyreoid axis.
4. Highest intercostal.
5. Posterior scapular.

The right inferior laryngeal nerve arose from the vagus at the level of the transverse process of the 6th cervical vertebra, it passed downwards, then turned round the inferior thyreoid artery, and finally pursued its usual course upwards between the œsophagus and trachea to the larynx. Where it was crossed by the inferior thyreoid artery it was held down by a slip of fascia. The left recurrent laryngeal nerve was normal with regard to its relations to the ligamentum arteriosum and arch of the aorta.

The thoracic duct on reaching the body of the 4th thoracic vertebra turned to the right along the lower border of the right subclavian artery, its course here being probably determined by the position of the abnormal artery. The duct near its termination split into two parts which opened separately into the junction of the right internal jugular and subclavian veins. On the left side a fair-sized lymphatic vessel passed upward on the vertebral column through the superior mediastinum, and joined a tributary from the left upper extremity to form a common trunk, which opened into the terminal part of the left internal jugular vein.

Case II. (fig. 3).[1]—In this specimen, from a female subject aged 63, the right subclavian artery sprang from the posterior aspect of the arch of the aorta, about half an inch beyond the origin of the left subclavian; it then passed upward and to the right, behind the left inferior laryngeal nerve, œsophagus, trachea, and right vagus nerve to the interval between the anterior and middle scalene muscles. It gave off the following branches :—

1. Vertebral.
2. Costo-cervical trunk.
3. Thyreo cervical trunk.
4. Internal mammary.

There was no "vas aberrans."

The 1st right aortic intercostal artery supplied the 3rd and 4th intercostal spaces and sent a small branch upward to anastomose with the highest intercostal artery.

[1] Dissected by Mr H. B. Eisenberg and Mr G. K. Burge.

The left subclavian artery gave off:—

1. Vertebral.
2. Highest intercostal.
3. Internal mammary.
4. Inferior thyreoid.
5. Transverse cervical.
6. Transverse scapular.

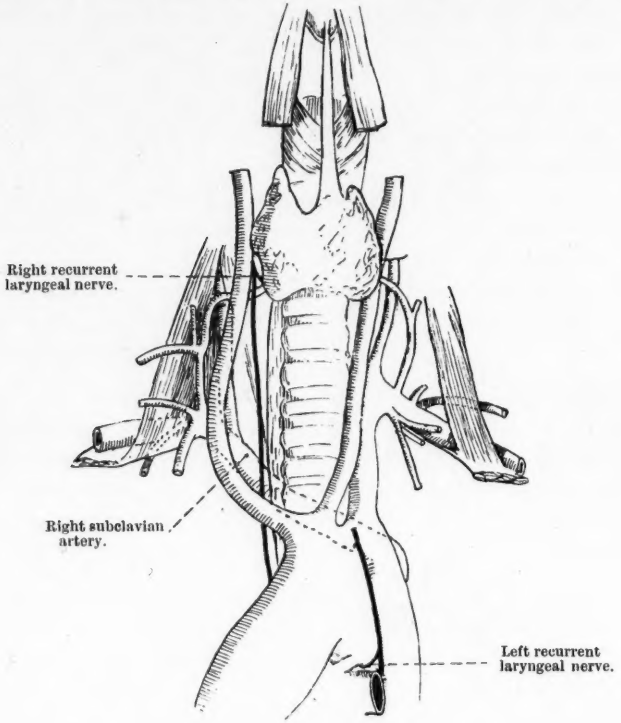

FIG. 3.

The right and left common carotid arteries arose from a short common trunk near the summit of the arch. The right inferior laryngeal nerve was given off opposite the 6th cervical vertebra, and after passing downward for a short distance turned round the inferior thyreoid artery and then passed upward to the larynx, between the œsophagus and trachea, as in Case I. The left inferior laryngeal nerve pursued its usual course. The thoracic duct had the normal course and relations, and terminated as usual at the junction of the internal jugular with the subclavian veins.

In an article by E. Pearce Gould (6), he expressed the view that in

those "cases in which the right subclavian artery arises directly from the arch of the aorta as its leftmost branch, that the abnormal vessel, which is a persistent part of the right dorsal aorta of the embryo, is most probably represented in the normal adult by an anastomosis between the 'vas aberrans' coming from the aorta, and a second aberrant artery given off from the subclavian. The latter is described in some text-books as forming a fairly constant accessory branch of the normal subclavian artery, which arises from this vessel close to its origin, and medial to the vertebral artery." This view differs from the theory previously held, namely, that the abnormal subclavian artery represents a persistent part of the right dorsal aorta of the embryo, *and that this is normally represented in the adult by an anastomosis of a branch of the highest intercostal artery of the right side with the aberrant artery from the aorta or 1st right aortic intercostal artery.* The objections to the latter part of this statement are (1) that according to this view the common longitudinal trunk of the right and left highest intercostal arteries would not be homologous, for the true homologue of the trunk of a right highest intercostal artery would, upon the left side, obviously be a part of the aortic arch, the commencement of the descending thoracic aorta; and (2) according to this theory the point of origin of the right highest intercostal artery in the normal condition ought to be medial to the vertebral artery and other branches of the subclavian artery (see fig. 5).

In a specimen of double aortic arch described by Professor Curnow, and preserved in the Anatomical Museum of King's College, the right arch, which is considerably larger than the left, gives off two branches, namely, the right common carotid and right subclavian; the latter gives off the right vertebral artery, thyreoid axis, internal mammary, and an artery which crosses the neck of the 1st rib and supplies the 1st and 2nd intercostal spaces. This appears to be the highest intercostal artery given off directly from the subclavian. It arises distal to the origin of the vertebral artery, and undoubtedly anastomosed with the 1st right aortic intercostal artery, which supplies the 3rd space. The left superior intercostal artery is also present, and evidently anastomosed with the 1st left aortic intercostal artery.

This specimen obviously supports the view expressed by Mr. E. Gould, namely, that the normal anastomosis of the highest intercostal artery of the right side with the 1st right aortic intercostal artery does not represent the terminal part of the right dorsal aorta of the embryo, for in the same subject there coexists a persistent distal part of the right dorsal aorta and an anastomosis between the highest intercostal artery of the right side with the 1st right intercostal artery, and a similar anastomosis is also

present on the left side, along with the persistent distal part of the left dorsal aorta. Whether the distal part of the right dorsal aorta is represented in the normal adult subject by an anastomosis of the aberrant branch of the aorta with an aberrant branch of the right subclavian is also doubtful.

In sixteen adult dissecting-room subjects in which we have specially looked for the aberrant branch of the right subclavian artery we could find no trace of it, and we therefore conclude that it is certainly not normally present in the adult.

Moreover, on examining a series of human embryos above 17 mm. in length, the distal part of the right dorsal aorta seems to have disappeared as completely as that part which lies between the 3rd and 4th arterial arches.

In a 10-mm. human embryo the distal part of the right dorsal aorta is considerably less than half the diameter of the left (fig. 4). The two vessels join to form the common dorsal aorta at the level of the 1st thoracic nerves. The common stem which divides into the right vertebral and subclavian arteries springs from the dorsal aorta as a segmental branch, which arises at the level of the 8th cervical nerves. The right dorsal aorta gives off one segmental artery of small size, below the origin of the subclavian artery. The next segmental artery (1st right aortic intercostal artery) arises below the point of union of the two dorsal aortæ.

In a 17-mm. human embryo belonging to Professor Waterston, which was obtained at an operation for tubal pregnancy, and which is exceptionably well preserved, the distal portion of the right dorsal aorta has almost disappeared. We have, however, been able to trace it (see fig. 5) from the common stem which divides into right vertebral and subclavian arteries down to its junction with the left dorsal aorta. This junction occurs just below the level of the bifurcation of the trachea.

About the middle of its course between these two points the lumen of the artery is obliterated, and the vessel can only be recognised by the concentric arrangement of the nuclei of its muscular wall. The lumen of the artery is occupied by an unstained hyaline substance which in some of the sections contains degenerated blood corpuscles. At the cephalic and distal ends of the artery, however, the vessel is more easily identified, and its lumen contains nucleated blood-cells continuous with those in the right subclavian artery and the aorta Below the point of union of the right and left dorsal aortæ the 1st aortic intercostal arteries are given off close together, and course laterally and upward behind the trunks of the sympathetic nerves. Each artery anastomoses, as in the adult, with a descending branch which appears to be the highest intercostal artery of

the corresponding side. The anastomosing vessel thus formed lies behind and lateral to the sympathetic trunk, whereas the aortic arch, the distal part of left dorsal aorta, and the degenerating distal part of the right

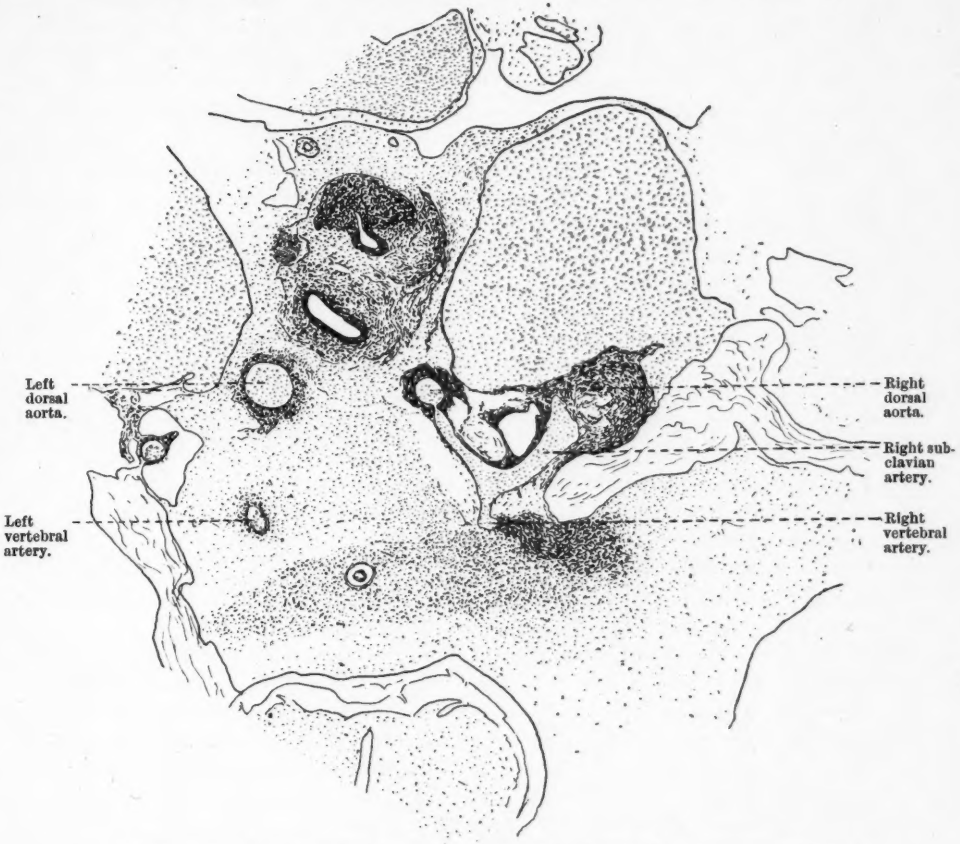

FIG. 4.—Transverse section through a 10-mm. human embryo showing the commencing atrophy of the right dorsal aorta and origins of the right subclavian and right vertebral arteries.

dorsal aorta lie ventral and mesial to the sympathetic trunk. It is obvious, therefore, that this anastomosis of the adult cannot represent the distal part of the right dorsal aorta, for in a 17-mm. embryo both the anastomosis and the right dorsal aorta coexist, and are seen side by side in the same sections. Further, if the first stage of the abnormal right subclavian artery

represented an enlargement of this anastomosis, the abnormal subclavian artery ought to pass dorsal to the sympathetic trunk instead of ventral to it.

Fig. 5, which is drawn from a linear reconstruction of the main vessels of this region, shows that the right subclavian artery consists of two parts, (1) a proximal portion of large size which courses vertically downwards from the bifurcation of the innominate artery to the origin of the common trunk which divides into the vertebral and the distal part of the right subclavian artery, and (2) a horizontal part which courses laterally into the limb bud.

The right vertebral artery is of large size. The left vertebral (not shown in the drawing) is much smaller. It is given off from the posterior aspect of the left dorsal aorta (aortic arch) about midway between the origins of the left subclavian and left common carotid arteries.

It will be observed that the left subclavian artery at this stage of development still arises below the junction of the "ductus arteriosus" with the left dorsal aorta, and is quite separate from the left vertebral artery, which as mentioned above, springs in this specimen as an independent branch from the posterior aspect of the left dorsal aorta.

The drawing also shows the position of the right and left inferior laryngeal nerves. The former passes backwards in the angle which is formed between the innominate artery and the first part of the right subclavian artery, and the latter round the termination of the "ductus arteriosus."

The "ansa subclavia" (a. Vieussensii) on the right side surrounds the common trunk which divides into the vertebral and the distal part of the right subclavian artery.

Both subclavian arteries arise at a relatively low level when compared with the position which they occupy in the adult. Moreover, the vessels springing from the arch of the aorta (innominate, left common carotid, and left subclavian) are separated by considerable intervals. At a later stage, when the heart has sunk down into the thoracic cavity and the lungs have grown upward on each side of these vessels, they come to lie close together at the summit of the arch.

In embryos of 20 mm. length and over the distal part of the right dorsal aorta has entirely disappeared, the right subclavian artery has become straightened out, and both this vessel and the left subclavian artery appear to have travelled upward with regard to their relation to the aortic arch. The left subclavian artery has apparently migrated in a direction towards the head along the dorsal aorta; its origin thus comes to be cephalad to the junction of the "ductus arteriosus" with the dorsal aorta and near the summit of the arch. This change in position is obviously

due to the sinking of the heart and its main vessels from the upper into the middle region of the thoracic cavity. The distal parts of the sub-

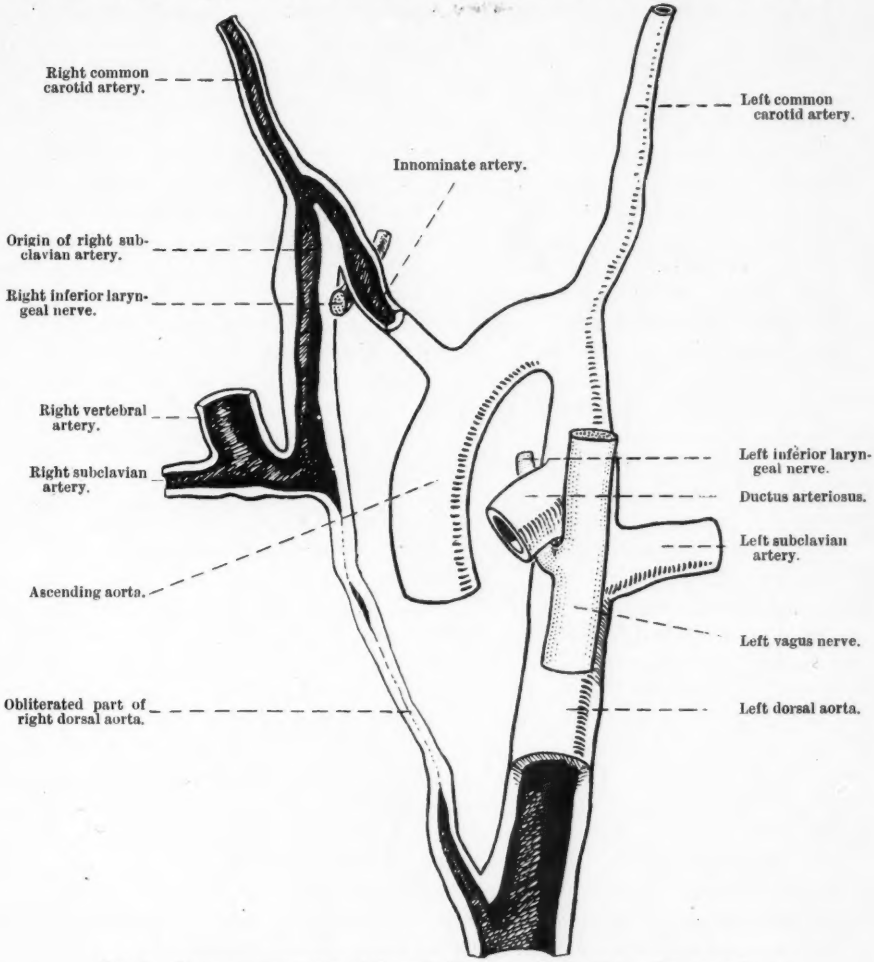

FIG. 5.—Linear reconstruction of the main blood-vessels of a 17-mm. human embryo, showing the obliteration of the distal part of the right dorsal aorta (mag. $\frac{7}{1}^{0}$).

clavian arteries, which pass out over the 1st ribs into the arms, do not participate in this movement. The origin of the right subclavian artery from the innominate artery is, however, brought down to below the level

of the 1st rib, and thus instead of pursuing a downward course it has to pass upward, in order to reach the 1st rib. The origin of the left subclavian artery, on the other hand, is displaced upward towards the summit of the arch.

It may be worth while here to draw attention to the remarkable manner in which the origin of certain arteries, when once these vessels are definitely formed, travel along the main trunks from which they spring. Thus the subclavian arteries are represented in a reconstruction of the arterial system of a 3·4-mm. human embryo as arising from the 7th dorsal segmental arteries caudad to the origin of the primitive cœliac arteries. In a reconstruction by Ingalls of a somewhat later human embryo (4·9 mm. long), the subclavian arteries arise cephalad but quite close to the cœliac artery. It will be observed also that they lie opposite the constriction in the alimentary canal, between the dorsal pancreas and the caudal end of the stomach. The cœliac artery when once established as a single vessel (see reconstruction of a human embryo of 5-mm. length, Broman) migrates in a caudad direction to its permanent position opposite the upper border of the 1st lumbar vertebra. The position of the subclavian arteries relative to the vertebral column and the first ribs, however, remains much more fixed, and it is this fixity in their position which causes the changes to take place in their relation to the larger blood-vessels which are drawn into the thoracic cavity along with the caudad movement of the heart.

A table showing the position at different stages of development of the three main ventral branches of the abdominal aorta, viz. the a. cœliaca, a. mesenterica sup., and a. mesenterica inf., is published in Keibel and Mall's *Manual of Human Embryology*. The table is followed by a discussion of the various theories which have been put forward in order to explain the method by which this "migration" is accomplished, and the author of the article, Dr Herbert Evans, sums up the evidence in the following words: "It seems to me most probable, however, that the identity of the three main vessels is established permanently very early, and that the great shifting is due to an entirely different phenomenon—namely, to the unequal growth of the dorsal and ventral walls of the aorta." The importance of recognising this means by which the relative position of different arteries or veins arising from the same trunk vessels become changed will be appreciated by a consideration of the changes which, during development, take place in the relative position of the subclavian and the cardinal veins.

The subclavian veins when first formed by the enlargement of the primitive ulnar veins enter the posterior cardinal veins caudad to the heart

and the common cardinal veins or ducts of Cuvier. As development proceeds they appear to travel cephalad, so as eventually to open into the anterior cardinal veins (figs. 6 and 7). The explanation of this change in position appears to be due to an unequal growth in the dorso-lateral and ventral walls of the upper part of the posterior cardinal vein. This is associated with a migration in a caudad direction of the common cardinal veins, which are drawn with the heart from the cervical region into the thorax. The junction of the common cardinal veins with the anterior and posterior cardinals becomes enlarged so as to form a triangular sinus, which

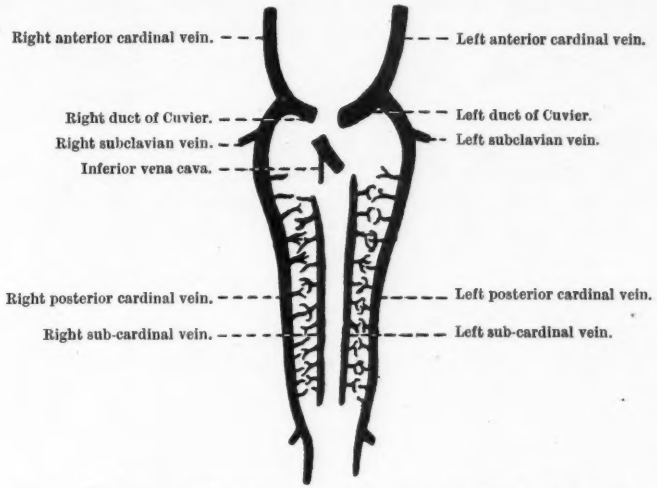

FIG. 6.—Early stage in the development of the veins, after Hochstetter, showing the entrance of the subclavian veins into the posterior cardinal vein.

receives the primitive ulnar vein (subclavian) on its postero-lateral aspect. This vein when first formed occupies a position opposite the interval between the 4th and 5th cervical nerves, but subsequently, when the embryo has reached a length of 10 mm. in its greatest diameter, it is found opposite the 8th cervical nerves, a position which it retains in the adult. The subclavian veins thus instead of migrating towards the head are at first drawn downwards in the opposite direction, and afterwards remain stationary, being fixed when these are developed by the 1st ribs, which prevent any further displacement downwards into the thorax.

The permanent innominate vein of the right side, and that part of the superior vena cava which lies above the entry of the vena azygos, will thus be formed, as far as their lateral wall is concerned, from the expanded upper

end of the posterior cardinal vein, viz. that part which lies below or caudad to the entrance of the subclavian vein. Similarly, on the left side the commencement of the left innominate vein, and the termination of the left superior intercostal vein, will be derived from the posterior cardinal vein and not the anterior cardinal, as is usually supposed.

To return from this digression to the immediate subject of our paper, we find that in the older embryos the anastomosis of the right and left highest intercostal arteries with the 1st aortic intercostal arteries may be

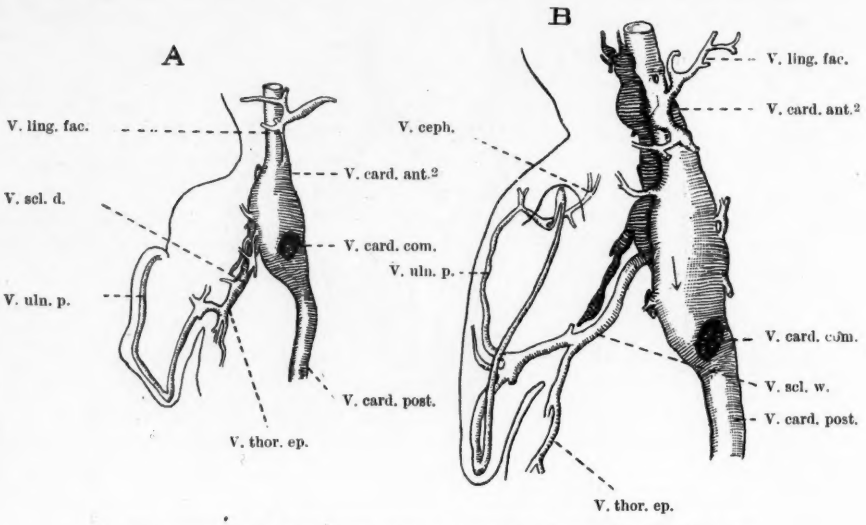

FIG. 7.—Reconstruction of the veins of the right arm in human embryo A, 11·5 mm., B, 16 mm. long. After F. T. Lewis.

quite easily traced. Moreover, the costo-cervical trunks, which give off the highest intercostal arteries, originate from the subclavian arteries, as in the adult, lateral to the origin of the vertebral arteries.

Now, if the anastomosis of the aberrant branch of the highest intercostal artery with an aberrant branch of the aorta or 1st right aortic intercostal artery represented the persistent right dorsal aorta, we should expect the costo-cervical trunk from which the intercostal branch arises to lie medial to the origin of the vertebral artery (fig. 5). Too much stress must not be put on this point, however, for the costo-cervical trunk or its highest intercostal branch is sometimes found to arise medial to the vertebral artery in the adult, as was pointed out by Professor Geddes in

an article published in the *Journ. of Anat. and Physiol.*, vol. xlv. p. 197. This relation might be explained on the assumption that as the proximal part of the subclavian artery is drawn downwards the origin of the terminal or distal part of the right dorsal aorta might be displaced to the lateral side of the vertebral artery.

The coexistence of the two vessels, viz. the abnormal right subclavian artery, and intercostal anastomosis in the same subject, in Professor Geddes's specimen, our own, and other cases previously alluded to, and also the development of the intercostal anastomosis in the 17-mm. human embryo, before the distal part of the right dorsal aorta has become completely obliterated, appears to us conclusive evidence that the abnormal origin of the right subclavian artery is usually due to the persistence of the distal part of the right dorsal aorta, and is not due to an enlargement of anastomosing aberrant arteries of the intercostal vessels.

In conclusion, we should like to express our thanks to Professor Waterston for the use of his valuable embryological material, and to Mr Walpole Champneys for the skilful manner in which he has executed the drawings.

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SOME RARE MUSCULAR ANOMALIES.

By Margaret O. Meek,
Girton College.

In a male subject dissected in Michaelmas Term 1913 a rare form of misplacement of the insertion of the latissimus dorsi and teres major muscles was found. The terminal ends of these muscles, united and not separated by the usually existing bursa, passed upwards and, becoming attached in

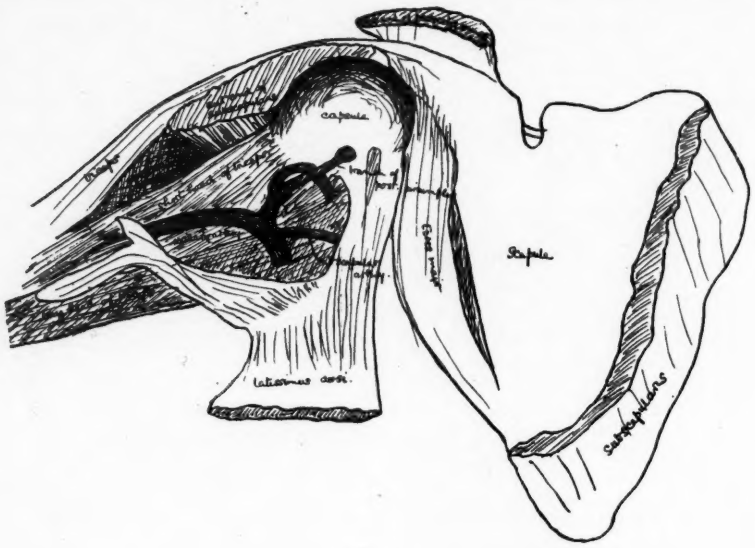

Fig. 1.

passing to the long head of the triceps, were finally inserted into the capsule of the shoulder below the coracoid process above the subscapularis insertion. The capsule was closed and did not show the usual perforation under the subscapular tendon (fig. 1). This anomalous insertion differed from any of the usual forms of the arcus muscularis axillaris in that it lay behind the axillary artery. The anomaly was present on both sides.

The same arm had a separate accessory extensor longus pollicis whose tendon lay in the same compartment of the dorsal carpal ligament as the

extensor digitorum communis, beside but separate both in belly and tendon from the extensor indicis. The first lumbrical was dicephalic, having an additional origin from the tendon of the extensor sublimis digitorum. On the ulnar side of the flexor profundus tendons for the middle and ring fingers there were separate lumbrical slips attached to the medial sides of the third phalanges, and the normally arising lumbrical for the little finger was inserted into the medial side of the ring finger.

Tensor Plicæ Douglasii.—In a female subject dissected during the present term there were on each side two small flat oblique muscular fasciculi under the fascia transversalis, attached laterally to the deep surface of the transversalis tendon, and medially inserted, one into the lateral margin of Douglas's fold, the other into the transversalis tendon 1 cm. above and

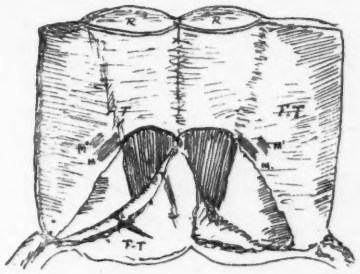

Fig. 2.

lateral to the fold. These are apparently varieties of the slip described by Professor Gruber (*Virchow's Archiv*, lxxx. p. 87) under the name "tensor laminæ posterioris vaginæ musculi recti abdominis." The upper one was about 20 mm. long; the lower larger, about 35 mm. long; the interval between the two was about 10 mm., and they lay nearly parallel, ascending at an angle of about 35°; each was about 15 mm. wide. Gruber's specimen was single on both sides, and was 10 cm. long. He gives references to three other examples of somewhat similar muscles. Other muscular slips in this locality have been described under the name pubio-peritonealis, but the present specimen is peculiar in its shortness, it having no pubic attachment, and in being double on both sides (fig. 2). The curious specimen figured by Gruber (*Bulletin de l'Académie Imp. de S. Petersbourg*, 1873) was single at origin but divided above into five bands. From his description it must have been a muscle of the same order as that now described.

ON THE SKELETON OF AN ECTROMELIC GOAT.

By J. A. Pires de Lima, *Professor of Topographical Anatomy in the Faculty of Medicine of Oporto (Portugal).*

In the Catalogue of specimens of abnormal anatomy at the Museum of the Medical School at Oporto, published in 1865, is registered a "skeleton of domestic goat without the left posterior extremity." The specimen was

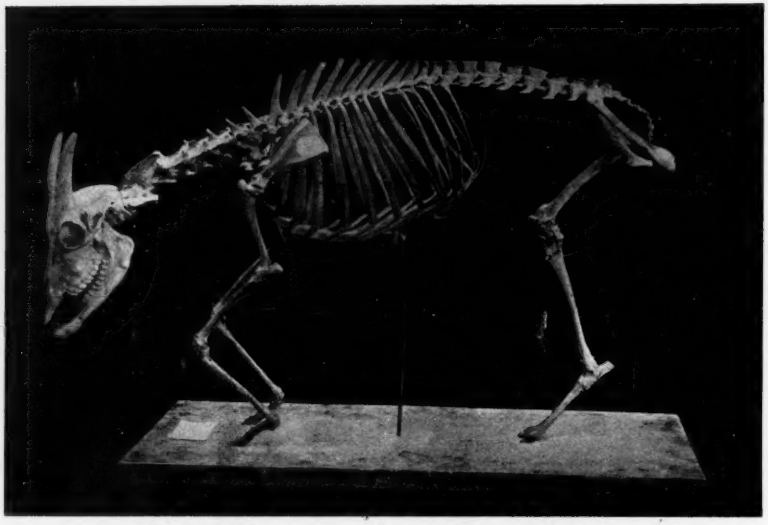

Fig. 1.—Skeleton of ectromelic goat seen from the left side.

prepared by Professor Costa Leite, and the skeleton belongs to a full-grown goat, as can be seen by the following dimensions:—The length of the vertebral column, from the external occipital protuberance to the extremity of the skeleton of the tail, is 860 millimetres. The greatest circumference of the thorax, taken at the sixth ribs, 515 millimetres.

Both these measurements were taken along the base of the spinous processes.

The skeleton (fig. 1) is in a fairly good state of preservation; it is mounted on iron rods and metal wire, and it still possesses some natural

ligaments. Of its left posterior extremity, the last three segments are totally absent, it being reduced to a very much deformed innominate bone, as we shall see on comparing it with the one on the other side, or with one of a normal goat.

Ilium.—The superior-external surface (fig. 2) presents the external iliac fossa slightly excavated. Normally this surface is divided into two portions by a longitudinal crest, homologous with the spine of the shoulder blade, according to Chauveau and Arloing (1). This crest ends generally in a tuberosity which is to be found in the crista iliaca (fig. 3, 1). In this skeleton, the vertex of the tuberosity (fig. 2, 1) is on the superior-external surface of the bone, at 15 millimetres distant from the crista iliaca and 1 centimetre from the external border. This is the greatest breadth of

FIG. 2.—The left os coxæ of ectromelic goat (superior-external surface).

the external zone of that surface of the ilium, whereas on the right side this dimension is doubled, as is the case in the bones of a normal goat. The distance between the internal angle (fig. 2, 2) and the external angle (fig. 2, 3) of the left ilium is 5 centimetres, whereas on the right side that distance is 55 millimetres; consequently, the ala of the abnormal ilium is narrower. In a normal goat the base of the ilium was also 5·5 centimetres. Both the superior-external and inferior-internal surfaces become very narrow at the posterior part.

In the goat, the crista iliaca is generally formed by a sharp border (fig. 3, 1-2), concave backwards, between the internal angle and the tubercle where the crest on the superior-external surface ends. From there onwards (1–3), the crista iliaca becomes very thick, rough, and sinuous. In the abnormal ilium the tuberosity of the external surface ends before the iliac crest (fig. 2, 1), which is rough and concave backwards along its entire length, getting gradually thicker from the internal angle

to the external one. To the latter (fig. 2, 3) there corresponds a large tuberosity, which does not exist on the other side, nor in two os coxæ of a normal goat.

The inferior-external border is blunt in front and ends up behind by a sharp crest, the most prominent point of which is 9 centimetres from the angle of the hip (fig. 2, 4). In the three other innominate bones which I have before me, next to the posterior ending of this border, before the cotyloid supracilium, there exists a large triangular depression with its base looking backwards (fig. 3, 5), which probably served for the insertion of the anterior portion of the rectus femoris, corresponding, I believe, to the impression above the upper part of the rim of the acetabulum, for the

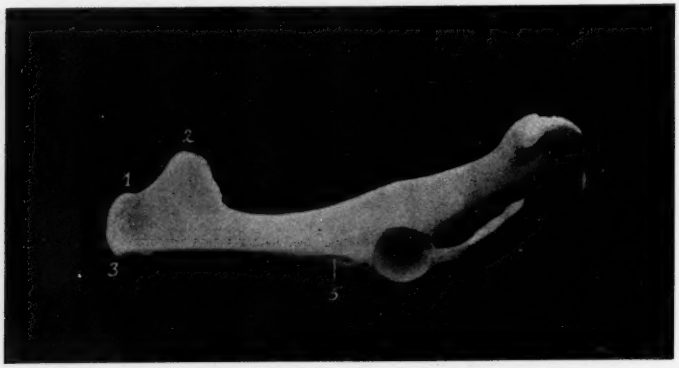

FIG. 3.—The left os coxæ of a normal goat (superior-external surface).

insertion of the rectus femoris in the human innominate bone. In both os coxæ of the normal goat I see the foramen for the nutritive vessels in this depression.

The incisura ischiadica major is blunt and nearly rectilinear. The posterior angle of the ilium, which cannot be called cotyloid, as there are no traces of an acetabulum, is very narrow and continues without the slightest demarcation into the ischium. The point of junction of the two bones probably corresponds to the most prominent part of the crest which I described in the posterior part of the inferior-external border (fig. 2, 4). The circumference of the bone, taken at its posterior angle, is merely 3·5 centimetres, whereas on the other side and in normal bones it is about 6·5 centimetres. At the thinnest point (neck of ilium), the perimeter is 28 millimetres, whereas on the right side and in the bones of a normal goat the circumference of the neck of the ilium is about 4 centimetres.

The relation between the greatest width and length of the os ilium, measured at the bottom of the acetabulum, constitutes, according to Chauveau and Arloing (1), a distinctive character of the innominate bones of goats and sheep. For the former, the index would be 0·47–0·58, whereas for the sheep it would be 0·62–0·76. The relation taken on the right os coxæ which I am studying is 0·50 ($\frac{55}{110}$); on the left, taking as the posterior limit of the ilium the prominence of its infero-internal border (fig. 2, 4), the index would be 0·55 ($\frac{50}{90}$), whereas in the two bones of the normal goat it is 0·45 ($\frac{55}{125}$).

Pubis.—It is completely missing on the left side, where there are not even vestiges either of the acetabular and symphysial branches, or of acetabulum, or of the pubic part of the foramen obturatum.

The one on the right side has the superior surface turned inwards and the inferior outwards, owing to the absence of the other pubis. It has the anterior border very short and concave, the posterior is normal, and the internal is nearly flat, being mistaken almost for the superior surface, which is deviated, as I have said.

Ischium.—The superior surface is narrow, very concave, and turned inwards. It measures but 2·5 centimetres in width, whereas the width of the right bone is 3·5, and of normal bones 4 centimetres. The inferior surface, contrary to what happens usually, is very convex and turned outwards.

The anterior border is more or less normal, and forms a notch (fig. 4, 1), the concavity of which is turned forwards and upwards, and represents the posterior or ischiatic part of the foramen obturatum, the only one that exists. The posterior border, very thick at its postero-external part, is curved, with its concave sides turned upwards and inwards (fig. 4, 2). Owing to this, the ischiatic arcade, formed by the posterior borders of the ischiums, instead of having the usual form of a lyra, resembles an italic *S* directed from above downwards and from the right to the left. The external border is turned upwards and is very slightly concave; the internal one is articulated normally with the one of the other side, forming the ischiatic portion of the symphysis pubis (fig. 4, 3), the only one that exists in this specimen, the synostosis of the two ischiums being complete.

The antero-external angle continues, without line of demarcation, with the posterior angle of the ilium and without existing between the two, as I have said, the smallest vestiges of the acetabulum. The antero-internal angle, instead of joining itself to the homonymous branch of the missing pubis, forms the anterior termination of the symphysis pubis, which in this skeleton is merely formed, as I have said, by the ischiatic portion. The postero-external angle, which forms the tuber ischiadicum, is very large, and is turned upwards, instead of outwards and forwards as usually

happens. The postero-internal angle (fig. 4, 4) forms with the one of the other side, in normal cases, the vertex of the ischiatic arcade.

The relation between the length of the ischium and ilium of the goat is, according to Chauveau and Arloing, about 70 per cent. In bones of a

FIG. 4.—Pelvis seen from above.

normal goat I found it 64 per cent. ($\frac{80}{125}$); in the right innominate bone of the ectromelic goat I found it 63·6 ($\frac{70}{110}$), and on the left side 77·7 ($\frac{70}{90}$).

The Pelvis.—On observing the superior surface, one notes that the pelvis, which is narrow and deformed, is turned backwards and to the left side. Both the crista iliaca and the iliac spines antero-superior and postero-superior on the left side are more at the back than on the right side. The apertura pelvis anterior is very irregular and continues backwards

and to the left with the ischiatic portion of the foramen obturatum on that side (fig. 4, 1).

These are some pelvimetric measures taken on this skeleton:—

Apertura pelvis anterior—sacro-pubic diameter (from the base of the sacrum to the anterior border of the right pubis)—10·5 centimetres, as much as in a normal goat; diameter bi-iliac, taken at the right acetabulum—5 centimetres (7 in normal goat).

Apertura pelvis posterior—from the apex ossis sacri to the posterior border of symphysis—13 centimetres; horizontal diameter taken at the right acetabulum—4·5 centimetres.

Limbs.—Both the ischiums and iliums are shorter than is usual, and consequently the innominate bones are smaller; but, in spite of that, the posterior limb is strong, and deviates somewhat towards the middle line, circumstances which helped the equilibrium of the animal The femur is a normal length (18 centimetres from the vertex of the trochanter to the inferior surface of the external condyles), but it is thicker than usual. Its circumference, taken at the middle of the diaphysis, is 55 millimetres, whereas in normal bones it is 52 millimetres. The tibia has normal dimensions, and the leg of the skeleton has no fibula. I did not see if this was due to any congenital cause.

On the contrary, the anterior limbs are small, the bones of the various segments being shorter and thinner than in the normal goat (fig. 1). The superior borders of the scapulæ of this skeleton measure 64 millimetres, and the posterior borders 100 millimetres. I found in scapulæ of a normal goat the following measurements: 80 and 150 millimetres respectively. Thus is one able to see that the powerfulness of the posterior limb is compensated by the small development of the anterior ones.

According to Isidore Geoffroy Saint Hilaire (2), the organs, regions, and systems whose formation and development are realised later are proportionately the most variable ones. This law, called "Law of late development," can be seen in the case which I described. It is well known that in man the ossification of the os coxæ begins independently by three centres: one for the ilium, which appears very early, in the third month of fœtal life; another for the ischium, which generally can be noticed before the end of the same month; and a third for the pubis, which only appears between the fourth and fifth month, and can even not exist till the sixth (3)

Chauveau and Arloing (1) say that in the soliped class it is also the ilium which begins to ossify first; the ischium appears somewhat later, and the pubis last of all.

I have already had occasion to describe (4) another anomaly, in which

the law of Saint Hilaire could be verified. In an abnormal auditory system which I studied, I noted the agenesis of the tympanic portion of the os temporale, which is generally the last to ossify. The absence of that part brought on the absence of the auditory canal and other morphological complications of the ear.

G. Saint Hilaire says that the bi-thoracic ectromely is the most common, and after that the uni-thoracic. The bi-abdominal ectromely is rare, and still more so the uni-abdominal one. The quadrupeds, deprived of one of their limbs, move above quite well with the three remaining ones, and can even jump and run. A he-goat with uni-thoracic ectromely, observed by that teratologist in the Museum of Natural History of Paris, walked, ran, jumped, fought with other he-goats, and managed, with some difficulty, to realise sexual intercourse.

G. Saint Hilaire had already noticed that the ectromelic quadrupeds have the odd limb more strongly developed and deviated towards the middle line.

Lesbre and Forgeot (5) describe a bovine fœtus, which they dissected, in which all the limbs are absent, and a dog, seven months old, in which the thoracic limbs were missing. The mother of that dog had acute chorea in the anterior limbs, and in the same litter had two bi-thoracic ectromelic pups.

The same authors refer to the skeleton of an adult cat in which the right anterior limb was missing, and to the skeleton of a kid, two months old, with absence of the right posterior limb. The posterior limb which did exist projected from the middle part of the body of the animal, whose pelvis was narrow, with the right innominate bone smaller, without acetabulum, and with premature synosteosis.

In the same paper is described the skeleton of a goat, two years old, with the left posterior limb ectromelic. The innominate bone was rudimentary, with no ischium, and the ilium reduced to a small bony sheet joined to the sacrum by a ligament. There was no acetabulum, and only the pubis was well developed, in opposition to the law of Saint Hilaire. The acetabulum of the other side corresponded to the middle line. The anterior limbs of the skeleton were strong, which does not happen in my case, and the posterior limb was long, which helped the animal in its progression.

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A NOTE ON THE POSTERIOR CRUCIATE LIGAMENT OF THE KNEE-JOINT.

By J. R. D. Holtby, M.B., B.S., *Chief Demonstrator of Anatomy, Trinity College, Dublin.*

Some months ago, when working at the lower end of the femur, I noticed that the impression for the posterior cruciate ligament varied, in some cases reaching up to the articular margin in its whole extent, in others only approaching the edge anteriorly.

An examination of fresh specimens appears to furnish an explanation of this peculiarity.

If the knee-joint be opened anteriorly and the synovial covering of the cruciate bands removed, it will be found that in the majority of examples the fibres of the posterior cruciate ligament attached to the anterior and inner lip of the intercondyloid fossa lie close to the articular margin in their entire extent, whilst in other cases they only approach the cartilage edge anteriorly, the remainder of the fibres lying on a much deeper plane. This difference will, on reflecting the anterior cruciate ligament, be seen to be due to the presence in the former series of an oblique band of fibres crossing the lateral and anterior aspect of the main posterior cruciate mass to be attached to the femur in front of the hinder half of the ligament proper, the oblique band gaining insertion quite close to the articular margin.

Posteriorly these oblique fibres, which we will call the anterior oblique portion of the posterior cruciate ligament, have a somewhat Y-shaped origin. The lateral limb arises from the posterior edge of the lateral meniscus, the medial from the lateral and anterior aspect of the main cruciate mass. As the band curves round the lateral edge of the latter there is often a small bursa.

The attachment of this oblique band has sometimes been described as a root of the posterior horn of the meniscus. This mistake probably arose from the idea that this band and Wrisberg's ligament are one and the same in origin. Robert (quoted by Fick) has shown that section of the oblique band has no effect on the security of attachment of the meniscus; and, moreover, it can easily be shown that the latter is cartilage covered beyond the point of origin of these oblique fibres.

There may be two oblique strands attached to the hinder margin of the

lateral meniscus: one of these, the above-described portion of the posterior cruciate ligament, passes always in front of this ligament; the other, or Wrisberg's ligament, lies posteriorly, and its tibial attachment, if any, is directly behind and separate from that of the cruciate mass.

Parsons showed that in most mammals the hinder horn of the lateral meniscus is attached not to the tibia but to the medial femoral condyle, but this root always passes posterior to the cruciate ligament and is probably represented now by Wrisberg's band. It does not, even in

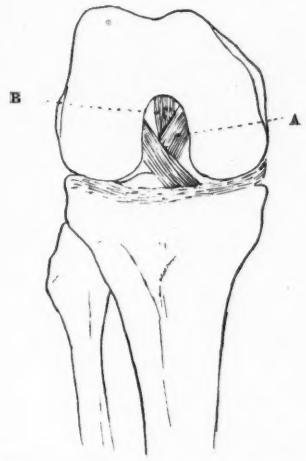

FIG. 1.—The knee-joint opened from in front and placed in the position of flexion. The synovial covering of the cruciate ligaments has been removed, showing

A, the anterior oblique band; B, the posterior cruciate ligament.

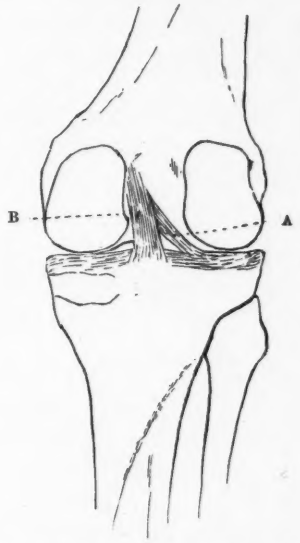

FIG. 2.—The posterior portion of the capsule of the knee-joint has been removed, and the joint placed in the position of extension.

A, lateral limb of the anterior oblique band arising from the lateral meniscus; B, the posterior cruciate ligament.

part, remain as the anterior oblique portion of the posterior cruciate ligament.

Many authors refer to these two oblique bands as being interchangeable, but I do not believe this to be the case. They are frequently found in association, as shown hereunder.

These anterior oblique fibres occur more commonly than has been supposed. Fick says he himself rarely found them, but that Barkow

states that he found an anterior oblique band in two and a posterior in three out of nine specimens examined.

In my series, the anterior band occurred in 75 per cent. of cases, and for some reason appeared to be more frequent in females than in males. It can readily be seen in young children.

It is probable that it chiefly comes into play during the lateral rotatory movement of the femur, or inward rotation of the tibia, at end of flexion, and that it then pulls the hinder edge of the lateral meniscus upwards and medially, so as to adapt its inner and hinder segment more accurately to the very oblique slope of the medial and posterior articular area on the lateral femoral condyle.

TABLE I.

	Number of Specimens examined.	Anterior Oblique Band present in.
Males	12	8
Females	8	8

TABLE II.—Association of the Anterior Oblique Band with Wrisberg's Ligament.

	Males.	Females.
(*a*) No anterior oblique band and no Wrisberg's ligament	1	0
(*b*) Anterior oblique band present. Wrisberg's ligament absent	1	2
(*c*) Wrisberg's ligament present. No anterior oblique band	3	0
(*d*) Both anterior oblique band and Wrisberg's ligament present	7	6

This table shows that the presence or absence of the anterior oblique fibres is independent of the occurrence of Wrisberg's ligament.

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BILATERAL ABNORMAL RELATIONSHIP OF THE VAGUS NERVE IN ITS CERVICAL PORTION.

By ALEXANDER GIBSON, M.A., M.B. (Edin.), F.R.C.S. (Eng.), *Professor of Anatomy, Medical College, Winnipeg.*

THE presence, on both sides of the body, of the vagus nerve lying anterior to the common carotid artery, instead of posterior to it, seems to be an abnormality sufficiently rare to be worthy of record.

From the operative standpoint, the possibility of this relationship of vagus to carotid is of some importance. In ligaturing the common carotid artery, inclusion of the vagus in the ligature is, to say the least, undesirable, and might possibly lead to serious consequences.

The earliest reference to the subject is made by Dubreuil, 1847: "I ought to mention a variation occurring in the relations of this trunk (common carotid) with the pneumogastric nerve, a variation which I have seen twice, but only on the right side, viz., the nerve was placed in front of the carotid and the internal jugular."

Malgaigne, 1859, makes mention of two cases of this abnormal relationship, but does not say on which side the abnormality occurred.

Macalister, 1868, reported a case occurring in an old female subject on the right side: "The carotid was flexed sharply about half an inch below its bifurcation; across the flexure the pneumogastric nerve coursed, at first from without inwards, and then again, completely to the outside." The nerve was connected to the artery by a process of the sheath, and could not be replaced in its usual position until the connecting bands of the sheath had been divided.

Cruveilhier makes reference to a case where a candidate was asked to ligature the left common carotid artery. A large nerve trunk was found lying anterior to the artery. Further dissection proved this to be the vagus.

Poirier and Charpy, referring to abnormalities of the vagus, say: "Il peut cheminer en avant des gros vaisseaux."

Quain says: "The pneumogastric nerve has been observed to descend in front of the artery."

Morris says: "The pneumogastric nerve may run in front of the artery instead of behind it."

Sappey makes no reference to the abnormality.

Testut also omits to describe it, either in reference to the common carotid artery or the vagus nerve.

The subject of this nerve artery relationship is discussed by Argaud and Cochet, 1908. They find that at the third month, on transverse section, the left vagus is anterior to the left common carotid at the level of the cricoid cartilage. Apparently only one specimen was examined. From examination of fifty adults, they conclude that, "in the majority of cases, the left vagus is situated in front of and a little to the outer side of the common carotid artery, and is frequently found in the anterior angle which this artery forms with the internal jugular vein." In the majority of their cases, the left vagus came in front of the left common carotid artery at the level of the upper border of the thyroid cartilage.

The latest reference to the subject is by Casali, in the *Anatomischer Anzeiger*, 12th July 1911. This investigator examined thirty subjects: in eleven of these he found the left vagus nerve anterior to the left common carotid artery. Of these thirty subjects, eight belonged to early infancy or to fœtal life. In all of these eight the left vagus lay anterior to the left common carotid. From this, Casali concludes that in all fœtuses the left vagus lies anterior to the left common carotid, the artery at that stage of life being of smaller diameter than the nerve. He suggests that after birth the greatly increased diameter of the common carotid pushes the nerve into the position usually described, *i.e.* lateral and posterior to the artery. In support of this theory, he found that in an infant one year old the nerve was placed lateral, but not posterior, to the artery, a position which may be regarded as intermediate.

That this relationship exists only on the left side, he explains by the statement that the left common carotid artery is of smaller diameter, and is situated more deeply than is the right common carotid, although the two vagi occupy the same coronal plane.

Casali refers to the results obtained by Argaud and Cochet. He adds to their findings his own results, omitting data obtained from fœtuses and very young children. The result is that of seventy-two subjects examined, eight presented the left vagus anterior to the left common carotid, *i.e.* 11 per cent. of cases; none presented the right vagus anterior to the right common carotid artery.

It would seem, therefore, that only three cases of the abnormality on the right side have been recorded, two of these by Dubreuil in 1847, and one by Macalister in 1868. In Dubreuil's cases we may infer that the relationship on the left side was as usually described. Macalister makes no reference to the left side, and the abnormal relationship on the right

side was associated with a flexure of the common carotid. The latest paper by Casali states specifically that in seventy-two subjects specially examined, the abnormality was not found on the right side. In this paper, also, an explanation is suggested which would require modification to make it explain the occurrence on the right side.

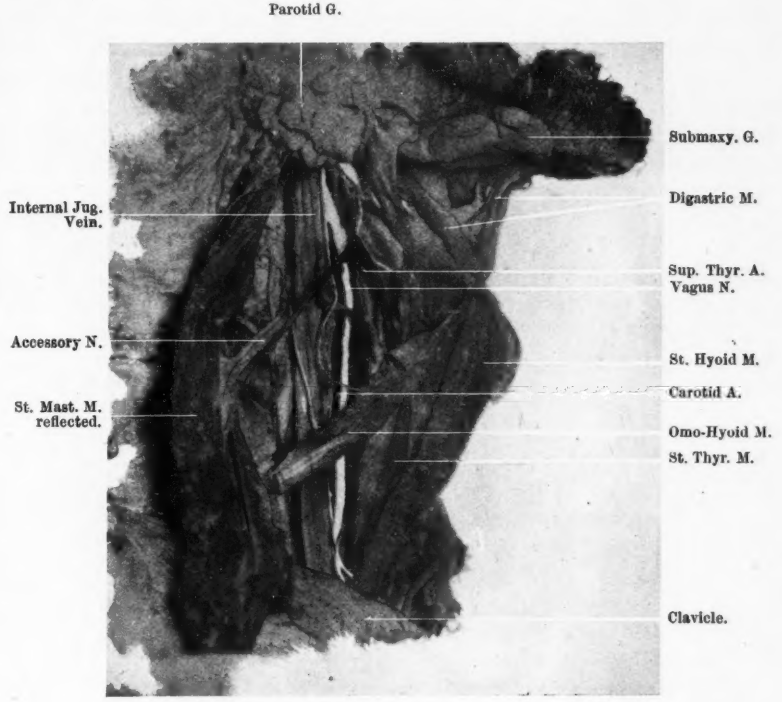

Fig. 1.

In January 1912 there was observed in the Anatomical Rooms of the University of Edinburgh a male subject, aged 59. This presented on both sides an abnormal relation of vagus to carotid.

A large nerve trunk was found lying in front of the right common carotid artery at the level of the upper border of the thyroid cartilage. The carotid artery showed no abnormal flexure. Its bifurcation into external and internal carotids occurred at the level of the hyoid bone. The nerve ran down anteriorly to the vessel until the lower limit of the neck was

reached. There it sheered off to the right, and entered the thorax by crossing the medial portion of the first part of the subclavian artery. The nerve was firmly bound down to the right common carotid artery by a process of the sheath. Not until this was dissected away could the nerve be replaced in its usual position, posterior to the artery.

The left side of the neck was at once examined, and there was found a condition of affairs corresponding precisely to that found on the right side. On both sides the nerve lay not in the angle between the internal jugular vein and the common carotid artery, but actually, for a part of its course, upon the anterior aspect of the common carotid.

In addition to numerous adult subjects, I have examined twenty-four fœtuses. Of these, six were about the sixth month, two about the seventh month, one about the eighth month, and the remainder (fifteen) full time. In no case was the vagus nerve situated anterior to the common carotid artery. My observations thus do not support the findings of Casali or of Argaud and Cochet.

I desire to express my indebtedness to Professor Arthur Robinson, University of Edinburgh, for permission to record this case, and for valued assistance in referring to the literature.

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THE CHELONIAN TYPE OF GENITALIA.

By FREDERIC WOOD JONES, D.Sc., *Professor of Anatomy in the University of London; London School of Medicine for Women.*

THE general arrangement of the reproductive system in the Chelonian reptiles is, of course, very well known. This knowledge is by no means recent, many of the early descriptions possessing a high degree of accuracy. The account given by Gerardus Blasius in 1674 will have to be referred to again in this paper, and it is worth quoting in full. After a good description of the other systems and organs, Blasius describes the genitalia in these words: "Penis notabilia habet corpora duo nervosa, quæ siquidem flatu distendantur, anteriora penis maximam in molem augentur, rigiditatemque summam acquirunt, cum apicis versus postica incurvatione aliqua, quo asperitates illæ, quas in parte postica seu inferiore penis notamus, liberioresque reddantur. Notabilis itidem in parte hac postica, que nempe cloacam ipsam spectat, fovea quædam singularis, insignis satis capacitatis, dum rigidus efficitur penis canalis formam adsumens; cum in pene viam aliam observare haud licuerit, hanc seminis ejaculatione inservire judicamus; anteriora autem penis distenta utero firmius inhærere. Asperitates vero adductas voluptati venereæ in fœmina exitandæ dictas esse" (1).

Every modern text-book of comparative anatomy furnishes excellent descriptions of the genitalia, and one would not hope to improve on these accounts. My excuse for recording the conditions present in a variety of representatives of the order, and in defining a more or less ideal type, is that I believe such a type to be a very important one—essential in interpreting the stages met with in higher classes, and in understanding the rudiments present in some of the lower ones.

I have already outlined, in a brief manner, what has forced itself upon me as the peculiarly pre-mammalian characters of the copulatory organ. In the Arris and Gale Lectures at the Royal College of Surgeons in 1914, I drew attention to what I imagined was the importance of a proper understanding of the Chelonian stage; and since that time the examination of a wider series of types has in every way strengthened my views (2).

It has, therefore, seemed to me desirable to place on record, in connected form, an account of the Chelonian genitalia merely as a preliminary

step to a fuller study of the genitalia of the Mammals which is being undertaken.

All Chelonians lay eggs enveloped in a definite shell, and this physiological fact is a guarantee that some method of copulation must be practised, and some degree of special copulatory organ is likely to be developed. When an egg is laid "shelled," it is necessary for the spermatozoa to be conveyed to it while still within the female passages, and before the shell membrane has been deposited. Shelled eggs imply internal fertilisation, and internal fertilisation requires the development of some intromittent organ in the male.

The hard-shelled eggs of the common European tortoise are well known; the calcareous shell is completed in the oviduct, and in living specimens purchased in the London markets, eggs in all stages of calcification are almost invariably met with, although their extrusion in this country does not seem to be a very frequent occurrence.

The marine Chelonians also lay their calcareous eggs on land, and the breeding habits of *Chelone midas* are very well known in consequence of the local demand for their eggs as an article of diet. This turtle not uncommonly lays its large batch of eggs some weeks after it has been received into the tanks of the London turtle merchants. Concerning one turtle (*C. imbricata*) I am well aware that there is at least a legend that the egg-laying habit is departed from, and that the young are produced alive. I cannot assert from first-hand knowledge that this legend is untrue, nor do I know any account of the breeding habits of the hawksbill given by an eye-witness. In its breeding habits it must be, at any rate, more elusive than *C. midas*, for in a place where the two forms are equally abundant the natives know nothing, beyond this legend, of the reproduction of *C. imbricata*, when the nests of *C. midas* are familiar and much sought objects.

For the most part the eggs of terrestrial forms are elongated, whilst those of the aquatic types, both fresh water and marine, are spherical. Concerning the intimate details of the reproductive habits of Chelonians I know but few observations. Courtship, so far as I have observed it among the land tortoises, commences, as Gilbert White has expressed it, by the male walking "on tiptoe; his fancy intent on sexual attachments, which transport him beyond his usual gravity, and induce him to forget for a time his ordinary solemn deportment" (3). From this stage of activity, courtship is advanced, as I have several times observed, by the male overtaking the female and, withdrawing his head beneath the shelter of his carapace, giving the hinder part of her shell a series of short, sharp blows with the overhanging margin of his dorsal shield.

This performance is repeated at frequent intervals during several days, but at length, after a prolonged series of resounding taps upon her shell, the female is arrested.

Copulation is prolonged, and, as Owen observes, "the development of the penis bears relation to the physical impediments to coitus, caused by the shape, extent, and completeness of the shell" (4).

In cloacal types of Vertebrates copulation is effected in a variety of ways. We may imagine that the most primitive method was for the cloaca of the male to be applied closely to that of the female, and for the spermatozoa to be passed from one open orifice into the other.

Such a stage is but a slight advance upon that seen in the frog, where the unshelled nature of the egg does not demand an actual internal fertilisation. The next advance may be supposed to consist in the eversion of the cloacal wall of the male, and the insertion of such an everted portion into the female cloacal orifice. Such a stage is seen in many of the more terrestrial of the Amphibia. In Gymnophiona the copulatory organ "simply consists of the eversible cloaca, which is regulated by a well-developed musculature" (5). In *Cæcilia lumbricoides* this everted portion may amount to some 5 centimetres.

In some of the Amphibia, however, copulation is still more complete. It is well known that some Amphibians have, to a great extent, emancipated themselves from their ancestral aquatic breeding-grounds, and although these forms have not adopted the habit of laying shelled eggs, they have missed out this stage, as it were, and passed direct to the culmination of the results of internal fertilisation in the production of living young. One such form is *Salamandra atra*. Of these animals Gegenbaur has observed, "Un indice d'un organe copulateur se remarque chez les Amphibiens (Salamandrines), sous la forme d'une papille faisant saillie dans le cloaque" (6). This rudiment of a copulatory organ is of interest, for it thickens and enlarges in the male during the breeding season. The condition seen in *Salamandra atra* I would regard as the prototype of the copulatory organ of the Chelonians (and the Crocodiles) as well as of the Mammals.

Although concerned only with the Chelonian reptiles, it is worth while to turn aside to note the very curious separation which exists, in the type of copulatory organs, between them and the Snakes and Lizards. There appears to be no common meeting-ground for these two types, and, although not by any means identical, the copulatory organs of Snakes and Lizards (scaled classes) have more kinship with those of the Elasmobranchs, while those of the Chelonians and Crocodiles (scutated classes) seem plainly to be elaborations of the condition seen in Amphibians.

The most generalised of the Reptiles—Sphenodon—is said to possess no distinct copulatory organ, and although I have had no opportunity of verifying the condition, it would seem to be comparable to that existing in Gymnophiona. If we accept the form of the external genitalia as our sole criterion (doubtless an extremely illogical standpoint), we may trace to the base of the Reptilian stock a type which, in its most primitive form, is akin to that of the Amphibia; and this type becomes modified in certain Reptilian orders to a condition which simulates that of the Mammals. There is, despite modifications, an obvious kinship between this type and that seen in the Ratitæ among the Birds, for in them also a median ventral specialised portion of cloacal wall is developed as a copulatory organ.

It is now necessary to trace the evolution of the "papilla," which, first developed upon the ventral wall of the cloaca in certain Amphibians, becomes the highly specialised copulatory organ of the Chelonians. In its simplest Chelonian form it consists of a thickening of the ventral cloacal wall; the thickening being in reality composed of two bilateral portions closely approximated to each other in the middle line; a slight median depression alone marking their bilateral disposition in the ordinary non-functionating phase.

In the Amphibians the papilla appears to be in large part glandular, and the enlargement during the breeding season is described as taking place by hypertrophy of this glandular tissue. In the Chelonia the papilla is composed of fibrous tissue containing large vessels and constituting a true "cavernous" erectile body. In its minimal Chelonian development this bilateral erectile mass stretches from the orifice of the urogenital sinus to a point not far distant from the cloacal outlet upon the ventral surface of the tail.

These two cavernous erectile thickenings are developed in the tissues of the ventral cloacal wall, and are, of course, covered by the lining epithelium and superficial layers of the cloacal wall. Between the two masses there is a median depression of the cloacal wall, a depression which leads from the orifice of the urogenital sinus to the terminal part of the cavernous bodies.

The functional rôle of such a copulatory organ is simple. The cavernous bodies become enlarged; they swell up, and their distal extremity is protruded from the cloacal outlet. With their enlargement, the groove between them deepens, and with complete erection it tends to be a closed channel rather than a mere groove (see figs. 1, 2, and 3).

The erectile bodies are obviously developed to provide an organ of sufficient rigidity to be everted from the male cloaca and to be inserted into the female cloaca, and we may at once name them as corpora

cavernosa. The groove, which in erection tends to become a closed channel, is for the conveyance of semen from the male urogenital sinus to the female cloaca, and I shall name it throughout the "seminal groove."

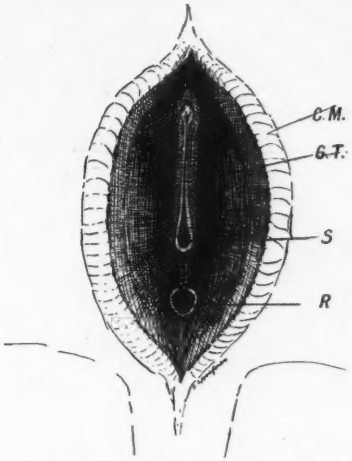

FIG. 1.—Diagrammatic view of the cloaca of a Chelonian. The cloaca is widely opened to show the intra-cloacal copulatory organ *in situ*.
C.M., cloacal margin; G.T., genital tubercle; S, opening of urogenital sinus; R, opening of rectum.

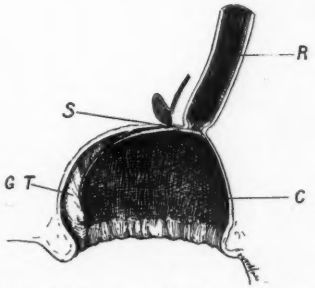

FIG. 2.—Diagrammatic view of the Chelonian copulatory organ in its quiescent intra-cloacal condition.
R, rectum; S, urogenital sinus; G.T, genital tubercle; C, cloaca.

FIG. 3.—Diagrammatic view of the Chelonian copulatory organ everted from the cloaca.

In the ordinary quiescent state of the parts, the products of the male urogenital sinus are discharged from the orifice of this chamber into the cloaca, and so to the exterior. In sexual functional activity they are

carried along the groove from the orifice of the male urogenital sinus to the extremity of the cavernous bodies, and so into the female cloaca.

Such is the primitive type of the Chelonian copulatory organ; and as such it is present most nearly in its simple condition in the marine turtles. Evolution from this stage takes place by, firstly, a general enlargement of the organ, and secondly, by a greater development of that portion of it which is free of the cloacal wall. In its most primitive form the erectile mass is simply a thickening of the cloacal wall, and is incorporated in this wall throughout the whole of its length. Increasing perfection is

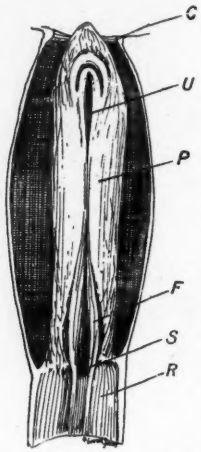

FIG. 4.—Copulatory organ of the male *Testudo tabulata*.
C, cloacal outlet; U, seminal groove; F, seminal guide;
P, penile body; S, urogenital sinus opening; R, rectal opening.

gained by the distal portion of the organ becoming free of the cloacal wall; and in its most fully developed form a considerable portion of the body of the penis is free, both during erection and in the quiescent state.

Specialisation of this primitive type, however, takes place in several ways. The corpora cavernosa may be greatly complicated. Firstly, they may develop coiled or S-shaped reserve portions, very similar to those seen in many Mammals: these coiled portions become straightened out in complete erection, and, thereby, add greatly to the length of the functionating organ (see fig. 5).

Secondly, there may be developed within their thickness varying degrees of "peritoneal canals"—spaces which communicate with the cœlom; and these may possibly help (as has long ago been suggested) in

the erection of the copulatory organ by imparting to the cavernous bodies a heightened intra-cœlomic pressure.

Thirdly, they may become generally enlarged so that they stretch cephalad to the cloacal orifice of the rectum and caudad almost to the cloacal outlet.

Again, by changes in the tissues of the ventral wall of the cloaca the seminal groove may be greatly elaborated. The first stage in this elaboration is the development over the cavernous bodies of bilateral ridges which

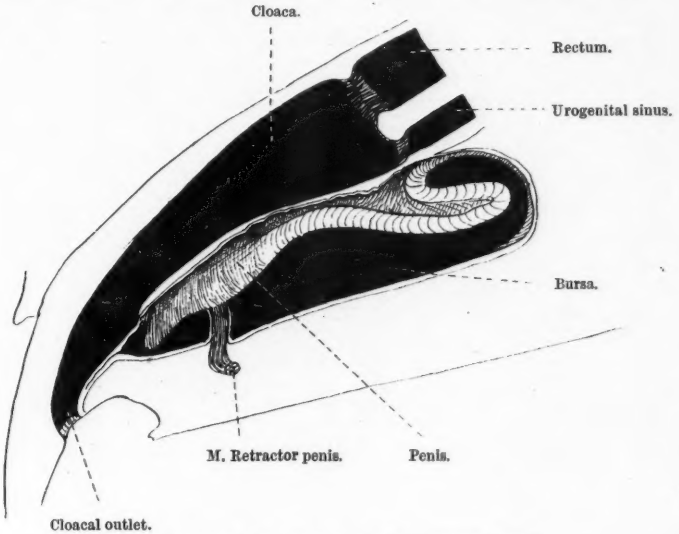

FIG. 5.—Section of the cloaca of a male *Clemmys leprosa*.

mark and accentuate the margins of the groove. These lips are coterminous with the extent of the groove, and since they help to deepen the seminal groove and to direct the semen, I shall name them throughout as the "seminal guides."

In the males of most of the terrestrial forms these seminal guides extend from (and into) the rectal cloacal opening to the extremity of the corpora cavernosa—and on this account they have been distinguished by some zoologists as the "plicæ recto-urethrales" (see fig. 6).

The next stage in the elaboration is the development of erectile tissue in these seminal guides; a stage seen well in sections of the copulatory organ of the males of most species; this erectile tissue is the prototype of the corpora spongiosa of the Mammalia.

When development has arrived at this stage, we have an intra-cloacal erectile copulatory organ which is cleft upon its free cloacal aspect, and is, in the nomenclature of human teratology, in a condition of complete hypospadias; but this hypospadiac condition is obliterated in erection by the meeting of the erectile seminal guides and the completion of the seminal canal.

Development of the corpora spongiosa goes further in most terrestrial species, and at the base of the copulatory organ a thickening occurs which

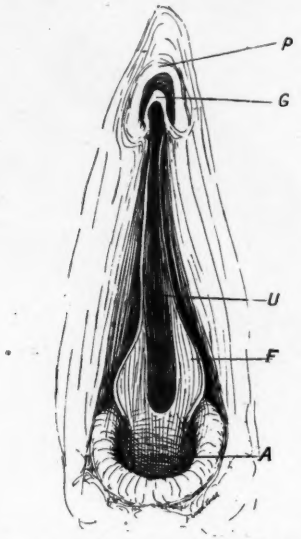

FIG. 6.—Well-developed copulatory organ of the male *Testudo elephantina*.
P, prepuce; G, glans; U, seminal groove; F, seminal guide; A, rectal opening.

is obviously the Chelonian homologue of the mammalian bulb of the corpora spongiosa. (The word "bulb" is here used for the thickening of the erectile mass, and not in its more correct—and Hunterian—sense as a synonym for the dilatation of the urethra within this thickening.)

Another specialisation of erectile tissue takes place at the distal portion of the organ, and this—the "asperitates" of Blasius—constitutes the homologue of the mammalian glans. This glans is of varying degrees of development in different species. It is more highly developed in the tortoises than in the turtles, and in the purely land-living types, as *Testudo*, it reaches its maximum degree of development (see figs. 6, 7, etc.).

When well developed, it consists of a trilobed mass of erectile tissue, the single lobe being distal and median, with the other two lobes arranged bilaterally at its base. The cloacal mucous membrane covering this glans is, as a rule, deeply pigmented. The seminal groove passes between the

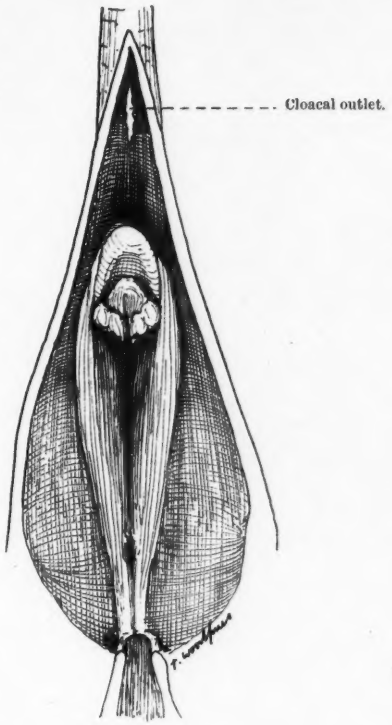

FIG. 7.—The cloaca of a male *Clemmys leprosa* opened from its dorsal aspect to show the structure of the copulatory organ.

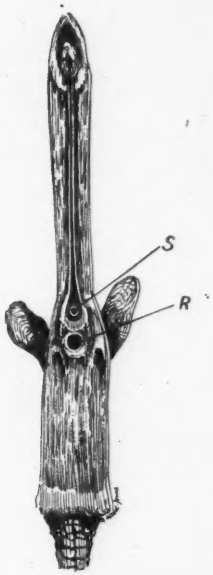

FIG. 8.—Copulatory organ of the male *Emys orbicularis*. The cloaca is opened along its lateral margins and the ventral wall and copulatory organ turned upwards.

S, urogenital sinus opening; R, rectal opening.

two basal lobes (these being in reality the expanded extremity of the seminal guides), and it grooves the distal lobe. Distal again to this median lobe is an erectile mass, usually bluntly pointed, which is the termination of the copulatory organ and is free of the cloacal wall. This free tip is surrounded by the redundant mucous membrane of the cloacal wall in such a way as to be partly concealed in the quiescent state. The mucous membrane reduplication which covers the distal portion of the quiescent

glans may be distinguished as the prepuce, and from this prepuce the organ is protruded in erection.

The copulatory organ of the female is in all its details similar to that of the male, except only that it is in every way less developed (see fig. 9).

The clitoris does not extend so near to the cloacal opening; it cannot

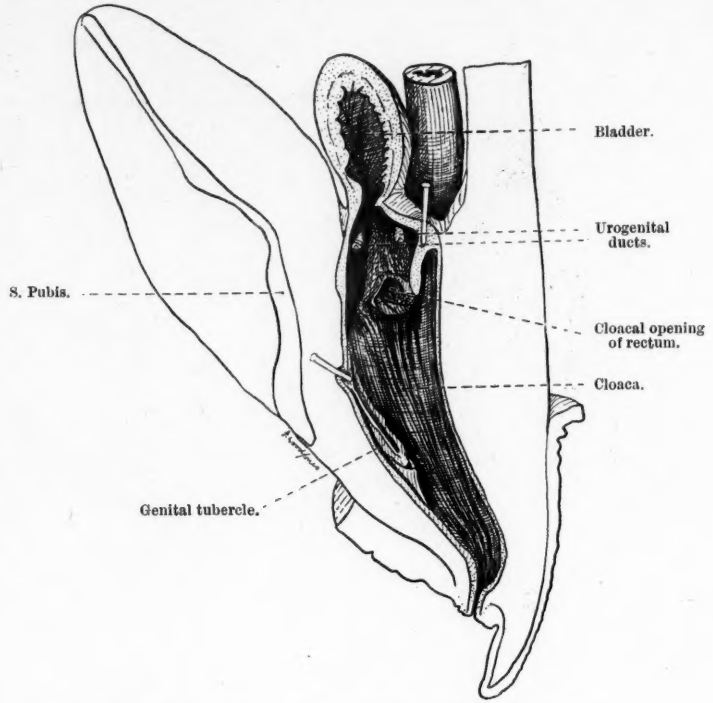

FIG. 9.—The cloaca and copulatory organs of a female *Chelone midas*.

be extruded from the cloaca, nor can it be seen by external examination of the cloaca in the living animal of any species I have examined (see fig. 10).

Although a somewhat rudimentary structure, this female copulatory organ is perhaps not to be classed in the same category as such vestigeal survivals as the male nipple, for it is not unlikely that it possesses some function in copulation. In these animals in which the seminal guides do not unite anatomically at their free edges, it is possible that the seminal groove of the female copulatory organ may assist the seminal

guides of the male in forming a complete seminal channel during copulation. It would seem quite possible that there is a mutual adaptation between the male and female copulatory organs in these animals by

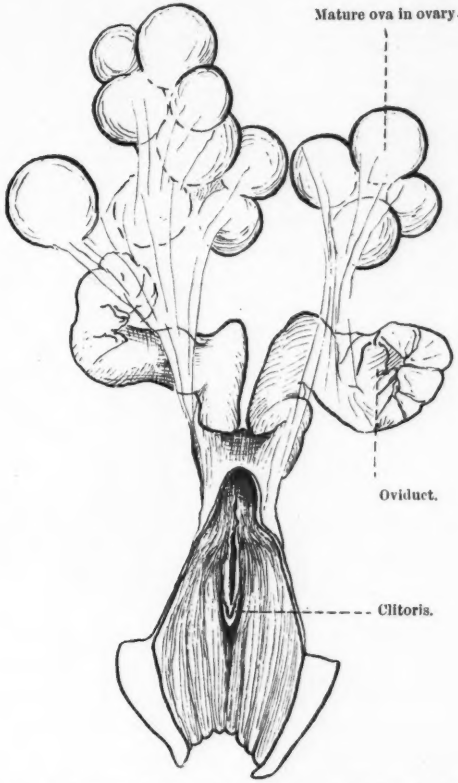

FIG. 10.—Ovaries, oviducts, and cloaca of a female *Testudo ibera*. The cloaca is opened from its dorsal aspect to show the copulatory organ.

which an opposition of their primitive dorsal surfaces assists in perfecting a channel for the passage of semen. With all the modifications displayed in the mammalian orders (which will be considered elsewhere) this approximation of the primitive dorsal surface of the male copulatory organ to the similar surface of the female is maintained.

The secondary adaptations of the Chelonian copulatory organ are

simple. It is erected and extruded doubtless by vaso-motor influences acting upon the vessels of the erectile bodies as in the Mammals. It is brought back again to its normal intra-cloacal station by special muscles, the retractors of the penis, which are inserted to its ventral aspect and run as ribbon-like bands around its sides to gain origin from the ischium (see figs. 11 and 12). The cloaca is under the control of the sphincter

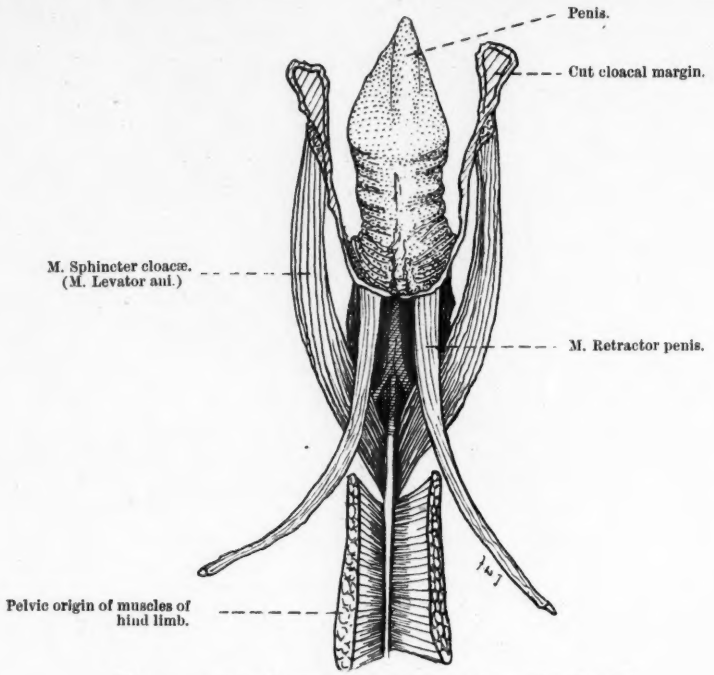

FIG. 11.—Penis and muscles of male *Testudo græca*, dorsal aspect.

cloacæ, which is the Chelonian homologue of the levator ani, and is attached on the one hand to the ventral portion of the pelvic girdle, and on the other to the vertebral skeleton of the tail.

In order to provide for a more complete extrusion of the copulatory organ, and to permit its free movement within the limits of the cloacal wall, a large subcloacal bursal space is developed in many species. The bursa is interposed between the cloacal wall and the ventral musculature of the hind limbs, and into it the penile body and the coiled ends of the corpora cavernosa project in the quiescent state (see fig. 5).

So much of description and illustration will serve to cover the general features of the genitalia of the Chelonian reptiles. This description and illustration I have considered necessary in a preliminary study, since it seems to me that no proper understanding of the ontogeny of the mammalian external genitalia may be come by until some clear idea of the phylogeny of the process is arrived at. The early phases of development, even of the human external genitalia, are very reminiscent of the adult Chelonian condition, and I think it may be laid down that: (1) appearing first in the Amphibia, the type of copulatory organ with which we are dealing is in its minimal development a mere intra-cloacal papilla—this papilla being developed upon the ventral wall of the cloaca; (2) that in Chelonians (and in Crocodiles) this papilla becomes specialised,

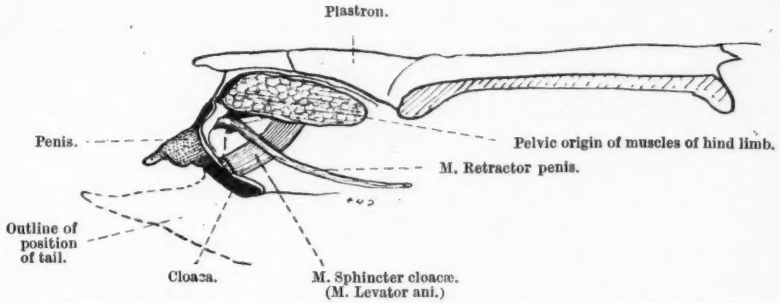

FIG. 12.—View from the left side of the copulatory organ of a male *Testudo græca* and its associated muscles.

in the ways specified, as a highly developed copulatory organ; although (3) in the Lizards and Snakes an altogether different type of copulatory organ is developed; (4) that considered on broad lines this Chelonian type of copulatory organ presents many striking resemblances to the embryonic condition seen in Mammals.

I will refrain from making any further comparison between this type of genitalia and those types seen in the mammalian orders, for this can only be done after the types prevalent in the different orders have been submitted to ordered review. I would, however, point out that the functional eversion of the intra-cloacal genital tubercle, which in Chelonians only accompanies sexual activity, becomes the prototype, under varying conditions, of normal mammalian development; and I would further note that an intra-cloacal genital tubercle but little modified from the Chelonian condition exists as an adult permanency in some Mammals, not only among the Prototheria, but even among the Eutheria.

If we may make any deductions at all from the type of the external genitalia, it would therefore seem probable that the mammalian stock arose early from some basal meeting-point of the Amphibians and the scutate Reptiles in a form in which cloacal eversion had proceeded to the specialisation of a portion of the ventral cloacal wall as a copulatory organ.

Towards the purchase of material used in this research assistance has been afforded from the "Dixon Fund" of the University of London.

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AN ANOMALOUS CORONARY SINUS.

By W. K. Hutton, M.A., M.B., *Lecturer in Anatomy, Queen Margaret College, The University of Glasgow.*

The heart which exhibited the abnormality to be presently described was found in a storage jar in the Anatomical Department of the University of Glasgow. It was one of a number of old specimens which had evidently been obtained, at various times, in the dissecting room, and then put aside for more detailed examination. The organ had been removed from the body along with the left innominate vein, the vena cava superior, and part of the root of each lung.

A slender left superior vena cava was present; its course and relations were those usually found in cases of persistence of this vessel. Traced from its union with the left innominate vein, about 4·5 cm. from the junction of this trunk with that of the right side, it passed caudally, ventral to the root of the left lung, and then dorsal to the left auricular appendage; thereafter, rapidly becoming considerably dilated, it coursed obliquely over the left atrium, to end in continuity with the coronary sinus.

Above the root of the lung it received a small tributary vein which may have been part of the left posterior cardinal.

The diameter of the normal vena cava superior, just central to the point where the azygos vein joined it, was, in the distended state, 3·5 cm.; that of the left cava, at a corresponding point, 5 mm. The coronary sinus was large; its length, measured from the point of entrance of the vena cordis magna to its right extremity, was 3·8 cm.; its diameter at the widest 1·5 cm. Both the sinus and the veins of the heart were filled with stone-hard blood clot, and when this was with difficulty removed, the following condition was found.

The great vein of the heart and the marginal vein of the left ventricle each emptied into an ovoid, sinus-like dilatation (see fig. 1),—2 cm. long by 1 cm. wide—the long axis of which lay parallel to that of the coronary sinus. The marginal vein joined this confluence at a right angle, and a fold resembling a small and imperfect valve lay at its ostium; the vena cordis magna opened at the left extremity of the enlargement, and in this part of its course was straight; when traced distally in the atrio-ventricular

sulcus it was found to be very tortuous. No valve guarded its mouth, but at the opening of the common dilatation into the coronary sinus there was

FIG. 1.—View of heart from behind.

A, bristle passed into sinus from confluence of vena magna and marginal vein; B, bristle passed into sinus from dilatation of posterior vein; C, bristle passed into sinus from confluence of vena media and right cardiac vein.

a complete two-cusped valve, which was unfortunately partially destroyed in the attempt to remove the blood clot.

A posterior vein of the left ventricle, of fair size, ended in a similar, but smaller, varicose swelling that opened, about the middle of its length,

into the coronary sinus; an imperfect, single-cusped, semilunar valve lay at the orifice.

The vena cordis media and the small, or right, vein of the heart—the latter, in this case, almost of the calibre of the vena media—joined one another to form a confluence before opening into the narrowed and somewhat pointed right extremity of the coronary sinus; the aperture was guarded by a competent two-cusped valve.

On the atrial wall of the sinus at its termination was an oval depressed area (A, fig. 2), about 10 mm. by 5 mm., its long axis coinciding with that of the sinus. This area corresponded in position to the usual opening of the coronary sinus into the right atrium, but such a communication was here

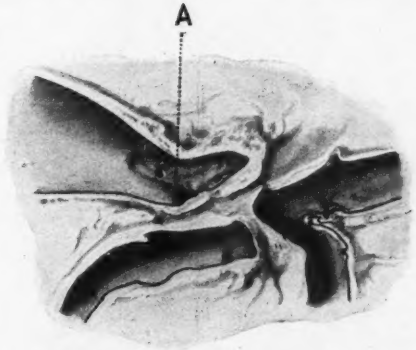

FIG. 2.—Right extremity of the sinus coronarius. (Natural size.)

A, the pitted, sunken area.

entirely absent; the floor of the depression had upon it a number of little pit-like markings, but trace of opening there was none.

In short, in this instance, the left horn of the sinus venosus,—the usual atrial aperture occluded—the left duct of Cuvier, and the central segment of the left vena cardinalis anterior, acted as a continuous efferent channel for the venous blood of the heart, carrying it to the left innominate vein, and so over to the right side.

On examining the right atrium there was found, in the usual position of the ostium of the coronary sinus, a shallow circular depression (B, fig. 3); its margins were ill defined, save dorsally, where it was bounded by that lower portion of the limbus fossæ ovalis which is derived from the inflection of the wall of the sinus venosus that separates the coronary from the caval segment of the right venous valve.

The floor of the depressed area was thin and was marked by shallow

grooves and pits; its extent could be covered by the tip of the little finger, and it abutted against the sunken pitted area already described as existing on the atrial wall of the coronary sinus.

Only the basal part of the Eustachian valve of the vena cava inferior persisted. On the other hand, on the septal wall of this vessel there was a very considerable remnant of the left venous valve (A, fig. 3); this had the form of a reticulated membrane, attached by one edge to the caval wall,

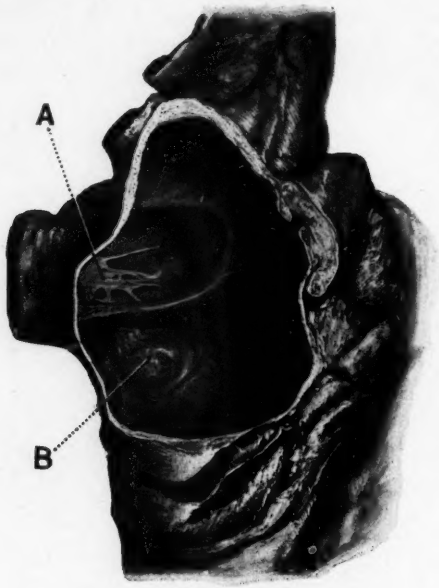

FIG. 3.—Right atrium, opened.

A, caval remnants of left venous valve; B, depressed area corresponding to position of the normal sinus opening.

and by the other, through the intermediary of delicate strings and bands, to the base of the septum ovale. Near the mouth of the vena cava superior a distinct semi-lunar endocardial flap, concave caudally, and covering the mouth of a small vein, probably represented another portion of the same valve.

It seems plain that the occlusion of the normal atrial opening of the sinus coronarius must have occurred at some period of development subsequent to the formation of that transverse connexion between the anterior cardinal veins which persists as the vena anonyma sinistra of the

adult, but before the continuity of the left duct of Cuvier and proximal portion of the left anterior cardinal vein was wholly interrupted. But while this is evident, the cause of the closure itself is by no means obvious, or easy of solution on embryological grounds, and, on the other hand, there seems to be no need in this case to postulate some ante-natal diseased state, as the heart was in other respects normal.

There appear to be two possible explanations of the anomaly under consideration; these are put forward in this note with all reserve, in recognition of the fact that our knowledge of the developmental changes attending the partial absorption of the sinus venosus into the atrial portion of the heart is as yet incomplete.

The position of the depression, described as existing in the right atrium, corresponds accurately with that of the normal sinus opening, and, further, is separated from the pitted area on the sinus wall by only a thin sheet of tissue; its situation and appearance give the impression of the occlusion of an aperture by the interposition of a tissue layer, rather than by a process of stenosis, and I suggest that this partition between atrium and sinus is either (1) a composite structure, the result of fusion between the coronary segments of the right and left venous valves, or (2) results from the presence, in earlier development, of an unusually voluminous Thebesian valve which has eventually fused with the margins of the opening of the sinus.

(1) Normally the lowermost, or ventricular, segment of the left venous valve disappears completely by fusing with the atrial septum, while that of the right persists as the coronary valve of Thebesius. If one suppose that in the case in point, the lower part of the left valve persisted not only in its caval division (as it has) but in its coronary segment as well, it seems not unreasonable to believe that such a complete valvular protection for the opening of the coronary sinus would be formed as might, when the pressure in the right atrium rose as a result of the augmented blood-intake due to the formation of the left innominate vein, become almost too effectual—a double flap valve.

The resulting back pressure in the coronary sinus would then tend to prevent the normal obliteration of the venous path between the left anterior cardinal vein and left duct of Cuvier.

At birth, the difference of pressure in atrium and sinus would be still further increased by the closure of the foramen ovale, and a fusion between the right and left segments of the coronary valve—similar to that which takes place between the septum primum and septum secundum—might occur, and lead to the complete occlusion of the coronary orifice.

(2) The normal sinus opening is, when the valve of Thebesius is well

developed, a triangle with two long sides,—the sinus septum and the coronary valve respectively—and its rhythmic closure is, in all likelihood, effected by the apposition of these two margins. If, however, the Thebesian valve were unusually voluminous, it is conceivable that it might act as a flap valve with results analogous to those just enumerated in the first tentative explanation of the abnormal condition under consideration.

As to the sinus-like confluences found in connexion with the veins of the heart, it seems not unreasonable to associate their presence with a certain amount of venous stasis that may be imagined to have existed throughout life. Such dilatations are found even in hearts with a normal coronary orifice—according to Poirier and Charpy the vena cordis magna was found to possess a proper sinus twice in 130 cases. Varicosity of the cardiac veins would seem to be a corollary to venous back pressure in the coronary sinus from whatever cause arising, since the valvular mechanism is anything but complete.

In the literature on the heart there are recorded but two other undoubted examples of occluded coronary ostium, for the brief notice of the case of Le Cat (1) 1738, merely states that in a child eight days old the coronary veins were found united as a single trunk, which, without entering the right auricle, emptied into the left subclavian vein; it is, of course, quite probable that the "single trunk" was the coronary sinus.

In 1885 W. Gruber (2) reported that, in an example of persistent left superior vena cava, occurring in a fifty-year-old man, the coronary sinus, with which the trunk was continuous, ended blindly without an atrial opening. The specimen was very similar to that described above. The great vein of the heart and marginal vein of the left ventricle opened into a common sinus; another dilatation was common to the vena media and v. parva; but the posterior vein of the left ventricle showed no enlargement. The ostia of the veins at the confluences, and the openings of these latter into the coronary sinus, were valved. In the right atrium, in place of the usual coronary aperture, was a groove, 14 mm. long and 7 mm. deep, that led into a *cul-de-sac* 6 mm. in depth: the free membranous atrial margin of this opening Gruber tentatively calls "Thebesian valve."

Anton Siding (3), who seems to have been unaware of Gruber's note of 1885, described in 1896 the conditions met with in the heart of an adult man removed at a *sectio* and sent to Professor Hochstetter. In this case also the left end of the coronary sinus was connected to the vena anonyma sinistra by a vessel 5 mm. in diameter. After receiving the great vein of the heart the coronary sinus, when traced to the right, was found to end in a blind conical extremity considerably (1·5 cm.) short of the site of its usual opening into the right atrium. Into the blind end of the sinus opened the

vena cordis posterior, which was constricted just distal to its termination. In the right atrium, and in the usual position of the normal sinus opening, was a narrow (5 mm. wide) aperture guarded by a feebly developed Thebesian valve. The opening led into a blind sack, about a centimetre in length, which extended as far as the occluded end of the coronary sinus.

Gruber's and Siding's cases resemble one another, and differ from the writer's, in that in both there was a definitive *cul-de-sac* in the atrium,—in the one smaller, in the other larger—occupying approximately the position of the normal sinus opening, and plainly representing some part of the right end of the coronary sinus. In both also a trace of the Thebesian valve existed, so that the suggestions put forward above to account for the occlusion in the present case will not hold good for these instances, which still remain unexplained.

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CONGENITAL ABSENCE OF THE APPENDIX OF THE CÆCUM.

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CONGENITAL absence of the cæcal appendix is an extremely rare abnormality. R. J. Berry, writing in the *Anatomischer Anzeiger* in 1895 (1), after having reviewed the literature on the anatomy of the appendix up to that date, and having reported 100 cases of his own, states that "some authors have described total absence of the appendix; I do not, however, believe that the appendix is ever absent except as the result of a previous excision." Later, in 1907 (2), the same authority refers to a specimen belonging to Professor Fawcett, and writes: "The fact remains that it is the only case on record of congenital absence of the appendix vermiformis."

In the systematic examination of 1352 subjects, in which special attention was given to the anatomy of the cæcum and appendix, there was only one case in which the appendix was absent, namely, Fawcett's.

	Number of Cases examined.	Absence of Appendix.
Monks and Blake (3) . . .	641	0
Fawcett and Blatchford (5) . .	350	1
Ribbert	161	0
Berry (2)	100	0
Treves (14)	100	0
	1352	1

Other undoubted cases of congenital absence of the appendix have, however, been recorded by Zuckerkandl, Bryant, Huntington, Meckel, Robinson, and others. I have myself seen three specimens. Two of these are in the Museum of the Royal College of Surgeons, England: Specimen 549 of the Teratological Series, described in the catalogue as "Part of the ileum and cæcum of a human fœtus in which the appendix is absent and the cæcum is very short," presented by Sir J. Bland Sutton; and Specimen 549·11, presented last year by Dr E. A. Chill. In this specimen also the cæcum was rounded and very short. It occurred in a new-born child, in which there was also an epi-cephalocele. The third specimen (fig. 1),

which forms the subject of this communication, was discovered in the Anatomy Department at King's College, University of London. It occurred in a woman who was certified to have died, aged sixty-three, from arterial sclerosis and heart failure. There was no scar in the abdominal wall, nor were there any signs of inflammation in the region of the cæcum. The cæcum was in the usual situation, and was normal in

FIG. 1.—A symmetrical type of cæcum, with absence of the appendix.

size and form. It was completely covered by peritoneum. The "tæniæ coli" converged to a point, on the medial and posterior aspect of the cæcum, 1¼ inches below the ileo-cæcal junction. No trace of an appendix was, however, visible from the outside. On examining the mucous membrane lining the interior of the cæcum, a small patch of what appeared to be adenoid tissue was found opposite the point of convergence of the three tæniæ coli, and in the position in which one would expect to find the orifice of the appendix.

The distal end or fundus of the cæcum was formed by a sacculation

which lay to the right of and below the point previously mentioned to which the longitudinal muscular bands converged. This case therefore differs from those described by Huntington; in one of which the cæcum was round and globular and the muscular bands converged to the lowest point of the pouch, and a second in which the cæcum turned upward and to the left, and ended in a sharp point, to which several lobes of epiploic fat were attached.

The very rare occurrence of total absence of the appendix is a matter of some surprise. On considering the subject from the standpoint of comparative anatomy, one would expect that an organ which is absent in such a large number of orders and species of vertebrate animals, and only present in higher types (anthropoid apes, certain rodents, and the wombat), would frequently be absent in man.

Vestigial structures are usually, though not always, variable in the extent of their development, and are frequently found to be absent altogether. This is especially the case when the structure or organ has no apparent functional importance. The fact that although the cæcal appendix varies very considerably in its length, form, and disposition, it is so rarely absent, supports the views put forward by Berry, Keith, and others regarding its functional importance.

From the standpoint of ontogeny, one would also expect congenital absence of the cæcum and appendix to be a much more frequent occurrence than it is. In a human embryo of 7·5-mm. length (Harvard College) the cæcal diverticulum is recognisable as a slight swelling on the distal limb of the intestinal loop. In an embryo of 17 mm. (Mall) this bulging is more pronounced and forms a rounded swelling, such as is seen in Specimen 629, R.C.S. Eng. In a later stage (in an embryo also 17 mm. in length) it becomes conical. Between 40 and 50 mm. a narrower distal part which will become the appendix can be distinguished from a wider proximal part which will become the cæcum. It is not, however, until after birth that a sudden diminution in the calibre of the gut marks off the root of the appendix from the cæcum, which is at this stage symmetrical in form, the appendix coming off from its lowest point. The asymmetrical form is not developed until a few years after birth.

Arrest of development may occur at any of these stages and give rise to:—

"Absence of the cæcum and appendix" (Robinson); "Rudimentary cæcum without appendix" (Sutton, Chill); "A cæcum having a blunt conical form without appendix" (Huntington); "A cæcum having a rounded symmetrical form, with the longitudinal muscular bands converging towards its apex, but without appendix" (Huntington); "Asymmetrical form of cæcum without appendix" (Author).

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A CASE OF CONGENITAL ABSENCE OF THE LEFT KIDNEY AND URETER.

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Congenital anomalies of the urino-genital system are of interest not only as teratological curiosities, but they are also of interest to the embryologist on account of the light that they sometimes throw upon normal developmental processes. Further, as in the case described below, they frequently have a very special and important bearing on surgical practice.

Description of Case.

Complete absence of the left kidney and ureter was discovered during the dissection of a male subject in the Anatomy Department, King's College, London.[1] The man, who was excessively fat, was certified to have died from chronic bronchitis, aged 56. The right kidney (fig. 1) was normal in position, and, as is usual in cases of single kidney, was greatly enlarged. It was rather more than double the average weight of the kidney in the male.

The measurements and weight of the "single kidney," compared with the normal organ, are as follows:—

	Single Kidney.	Normal Kidney.
Length . . .	5⅞ ins. (150 mm.)	4⅛ ins. (105 mm.)
Width . . .	2⅞ ,, (72 ,,)	2⅜ ,, (60 ,,)
Thickness . . .	2¼ ,, (55 ,,)	1¼ ,, (30 ,,)
Weight . . .	11 oz. (315 grm.)	4½ oz. (130 grm.)

The right kidney was elongated in the vertical diameter, and distinctly lobulated, but was otherwise normal in appearance. Both suprarenal bodies were present, and they were normal in size and position. The left, however, differed in form; for, owing to absence of the left kidney,

[1] I have to thank the students who were engaged in the dissection of the subject, Mr H. O. Gunewardine and Mr A. M. G. Mishad, who first drew my attention to the defect.

the upper pole of which normally exerts pressure on the under surface of the suprarenal body, this surface, instead of being concave, was convex.

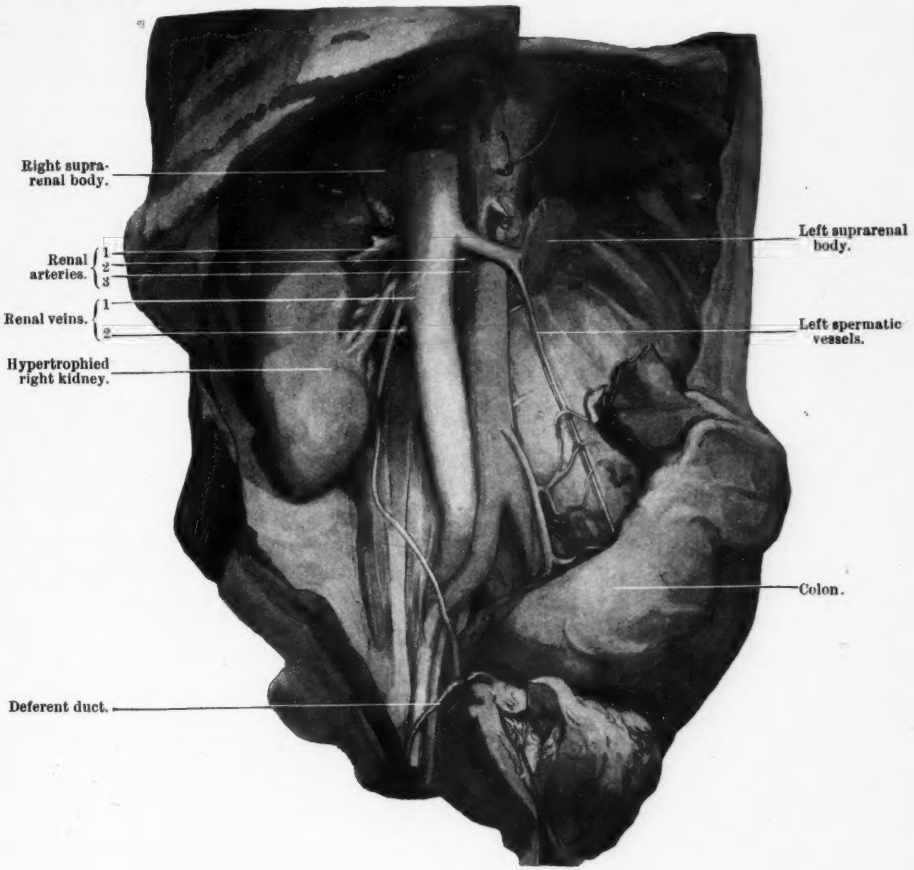

FIG. 1.—Absence of left kidney and ureter.

The ureter on the left side was completely absent, and there was no indication of a left ureteral orifice in the interior of the bladder. The pelvis of the right ureter was larger than usual, but in other respects it appeared to be quite normal.

The testis, epididymis, deferent duct, and seminal vesicle of the left

side were present but imperfectly developed. The veins of the spermatic cord were large and somewhat varicose. The cavity of the tunica vaginalis was obliterated. On section, the testis appeared to the naked eye white and fibrous. It was dense in consistence, and the tubules appeared to be imperfectly developed, and imbedded in dense fibrous tissue. The epididymis appeared to be formed almost entirely of a venous plexus supported by a loose connective tissue. The deferent duct was represented by a thin fibro-muscular band, which was with difficulty distinguished from the other constituents of the cord. It pursued the normal course, and terminated in the usual position at the base of the prostate gland by joining with a fibrous cord representing the duct of the seminal vesicle. The left seminal vesicle was, however, quite rudimentary, and no lumen could be recognised in it; nor could the opening of the common ejaculatory duct be found in the floor of the prostatic urethra.

The bladder was contracted and its walls greatly hypertrophied As previously stated, only one ureteral orifice, the right, was present. The hypertrophy was obviously due to urethral obstruction. There was, however, no definite stricture, but rather a general narrowing of the canal, which was sufficiently marked to prevent the passage of a medium-sized sound. Whether the small size of the canal was a congenital stenosis, or the result of inflammation, it is difficult to decide, more especially as I have been unable to obtain any history of the case. As, however, there were no obvious signs of inflammation, I am inclined to regard the small size of the urethra as a congenital defect associated with imperfect development of the left half of the urogenital sinus.

Microscopical Appearance of a Longitudinal Section of the Testicle.

The organ was cut entire, stained with hæmatoxylin and counterstained with eosin. The outer fibrous tunic (t. albuginea) was greatly thickened. The substance of the organ (fig. 2) did not show the normal subdivision into compartments or loculi, by septa converging from the periphery to the mediastinum, but consisted of an irregular network of coarse bands, in the meshes of which the seminiferous tubules were embedded. The tubules differed markedly in appearance in different parts of the organ. In some parts the epithelium of the tubules had entirely disappeared, and the walls were greatly thickened, so that the lumen was reduced to a mere chink. Some tubules, on the other hand, were more or less completely filled with epithelium, the cells being mostly large, and rounded or polygonal in shape. They contained large spherical nuclei, the chromatic

elements of which stained deeply with hæmatoxylin. Scattered about in the region of the mediastinum and between the tubules were other cells of an epithelial type; these, the "interstitial cells," formed irregular

FIG. 2.—Section through left testicle from case in which left kidney was absent, showing imperfect development of seminiferous tubules and group of interstitial cells.

groups, which, owing to the degeneration of the epithelial cells in the tubules, appeared more than usually conspicuous.

In the epididymis the tubules were large and replaced by a vascular plexus. The walls of the tubules were greatly thickened, and the epithelium degenerated.

Dr Shattock, who very kindly examined one of the sections for me,

stated that the condition was very similar to that of an undescended testicle, and that he believes the thickening of the walls of the tubules to be due to irritation produced by toxic products from the degenerating epithelium.

Arteries.

The left renal artery was entirely absent. The right kidney received three arteries, which arose close together from the abdominal aorta. They occupied a normal position behind the inferior vena cava. The first or highest of these was given off at the level of the superior mesenteric artery. It supplied the upper part of the organ and a branch to the right suprarenal. One of the main terminal branches entered the anterior surface of the kidney above the hilum; another passed into the upper part of the hilum. The second and third branches arose from the right side of the abdominal aorta, one in front of the other, and both of them about half an inch below the level of the first. The second passed in front of the renal vein and pelvis of the ureter, the third behind both. They supplied the middle and lower part of the kidney.

The left suprarenal body received its blood-supply from the left inferior phrenic, the aorta, and the left spermatic arteries.

The right suprarenal body was supplied by the right inferior phrenic, aorta, and highest right renal artery.

There were two left spermatic arteries; one arose at the level of the superior mesenteric artery from the left side of the aorta, the other about half an inch below this from the same side of the aorta. They joined below to form a single vessel.

Veins.

The "left renal" vein was represented by a small trunk formed by the union of the left suprarenal vein with the left spermatic vein. The suprarenal was joined by the left inferior phrenic vein. The main vein received a small tributary from the second left lumbar vein. This vessel probably represented the communication of the left posterior cardinal vein with the transverse anastomosis joining the subcardinal and posterior cardinal veins; this anastomosis normally forms the terminal part of the left renal vein.

Two right renal veins were present, a larger one above, which joined the inferior vena cava just below the level of the vessel representing the left renal vein, and a smaller vein below, which joined the inferior vena cava half an inch below the level of the former.

Structure and Nature of Enlargement.

On making a longitudinal section through the enlarged right kidney, it was obvious that the pyramids were also enlarged, and that the general structure of the organ was coarser than in the normal kidney. Further, on counting the number of pyramids visible in the section, I found that, notwithstanding the large size of the organ, there were only nine, which is approximately the number visible in a similar section of a normal kidney.

In making comparison with the normal kidney, I counted the number of pyramids visible in a mesial longitudinal section of twenty kidneys obtained from the dissecting room, and found that the average in twelve right kidneys was 9·9, and in eight left kidneys 9·5. Thus in the normal kidneys, though only half the size, there were in the average rather more pyramids visible in the mesial section, than in the enlarged single kidney.

Moreover, on examining sections of the enlarged "single kidney" with the microscope, and comparing these with the normal, the glomeruli and tubules were seen to be much larger than in the normal kidney. The average diameter of twenty-five glomeruli in the "single kidney" was 0·2 mm.; in a normal human kidney used for comparison the average was 0·13 mm. There was a similar enlargement of the tubules of the "single kidney."

Further, on counting the number of glomeruli visible in a given area of the "single kidney," which I accomplished by enumerating those falling within an area of 16 squares ruled on a glass inserted inside the ocular of the microscope, I found that the average number falling within these 16 squares in 50 counts was 2·8 in the "single kidney," 5·5 in the normal. The number of glomeruli falling within the given area, in the "single kidney," thus averages about half that in the normal.

Average number of glomeruli seen in 50 counts of 16 squares.		
Single kidney.	Normal kidney.	
2·8	5·5	$\frac{5·5}{2·8}$ = approx. 2.

The enlargement of the kidney is thus a pure hypertrophy, or enlargement by increase in the size of the constituent elements, and not a hyperplasia, or enlargement by increase in their number. In other words, the total glomeruli in the enlarged "single kidney" must have been approximately equal in number to those contained in a normal kidney, in spite of the great difference in size between the two.

The credit of first pointing out that the enlargement in a case of "single kidney" is a pure hypertrophy is due to Professor A. E. Boycott, who cut serial sections of blocks having a definite weight from kidneys in the rabbit. One of these was taken from a case of single kidney, the others from two "controls." He counted the glomeruli with the aid of camera lucida drawings. My observations on the human subject must therefore be regarded as confirmatory of his work carried out in the rabbit.

Practical Considerations.

The possibility of one kidney being absent has an important bearing on modern surgical practice, and more especially with reference to the operation of nephrectomy.

In considering these cases it is necessary to distinguish between:—

1. Congenital absence of one kidney, including those cases in which one kidney is rudimentary and functionless.
2. Fusion of two kidneys into a single mass (horse-shoe and disc-shaped kidneys).
3. Atrophy or destruction of a kidney as the result of disease.

Secondly, it is of importance to have some idea as to the frequency of these conditions; and thirdly, we must consider the signs and symptoms which would lead one to expect the absence of one kidney, or the fusion of two into a single mass.

The frequency of congenital absence of one kidney, fusion of two kidneys, and atrophic kidneys has been very thoroughly worked out by Sir Henry Morris, who gives the following averages derived from the reports of post-mortem examinations conducted at four London hospitals, combined with published statistics of other writers:—

1. Congenital absence of one kidney . 1 in 3,992 or ·25 per 1000
2. Fusion of two kidneys (horse-shoe, etc.) 19 in 18,244 or 1 per 1000
3. Atrophied, small, shrunken, or wasted kidneys . . . . . 59 in 8,178 or 7 2 per 1000

Congenital absence of one kidney is thus seen to be an extremely rare abnormality. From the surgical standpoint, however, in neither of the first two groups should nephrectomy be performed; and probably, in the greater number of cases belonging to the third group, the operation would be contraindicated, as the atrophic kidney, if the other was removed, would be unequal to the strain which would suddenly be thrown upon it. The total number of cases, therefore, falling into one or other of these three groups in which nephrectomy is contraindicated is about 8 per 1000. This number is, however, considerably increased by the fact that when one kidney is absent, or is atrophied, the other kidney is frequently diseased. Thus it is probable that the proportion of cases in which one kidney is

absent would be greater in those subjects suffering from symptoms of renal disease than in the total number of cases examined "post mortem" in a general hospital. Moreover, the importance of recognising the condition is so great, that in all cases in which nephrectomy is contemplated a careful examination should be made to ascertain the existence and condition of the opposite kidney.

The most important signs of absence of one kidney are:—

1. Absence of an ureteral orifice on one side of the bladder.
2. Absence of the "kidney shadow" when the patient is examined with X-rays.
3. Some congenital defect of the external organs of generation on the same side.

In one instructive case described by Guthrie and Wilson, and operated on by W. J. Mayo, absence of the left kidney and ureter was diagnosed by cystoscopic examination previous to an operation for the removal of a tumour, which proved to be the uterus and upper part of the vagina distended with retained menstrual fluid. The lower portion of the vagina, the left ovary and Fallopian tube were completely absent. The labia majora were rudimentary, and the labia minora absent. The case emphasises the importance of cystoscopic examination of the bladder, and also the importance of examining the external genital organs, which, in congenital absence of one kidney, are frequently imperfectly developed on the same side as that on which the kidney is absent.

In the case which I have described, the atrophic condition of the left testicle and deferent duct would, taken in conjunction with absence of the ureteral orifice, have formed a very important clue to the absence of the left kidney.

Abnormalities of the genital organs are, however, not the only congenital defects which may accompany absence of one kidney. In a specimen (558·4) presented by Frank Deas to the Royal College of Surgeons, England, last year, absence of the right kidney was associated with imperforate anus and hydrocephaly. In specimen 702·2, also added to the Museum of the Royal College of Surgeons last year, imperfect differentiation of the sexual organs in a newly born child is combined with an imperforate condition of the rectum. There was also an imperfect penis and scrotum, and no sexual glands.

In my own experience of teratological specimens, I find that one congenital defect is nearly always associated with other defects, and often of some quite distant part. The frequent occurrence in one subject of congenital defects in different and often distant parts of the body

indicates, therefore, that *special* care should be taken to ascertain whether one kidney is absent, in all those cases in which nephrectomy is proposed and some congenital defect, *e.g.* an "accessory auricle" or "club foot," is present.

It is curious that, since writing the above sentence, I have received a letter from Mr Frank Deas, informing me that the child from whom specimen 558·4 was prepared also "had a curious deformity of the hands, which resembled feet." This was not stated in the description in the catalogue.

Absence of the ureteral orifice on one side does not necessarily involve complete absence of the kidney on the same side; it may be present but in a cystic condition, as in a case of Sir J. Bland Sutton's, reported by Sir H. Morris, or it may be otherwise diseased, as in a specimen (648·6) in the Museum of the Royal College of Surgeons, England, presented last year by Dr F. Mott. In this case the termination of the left ureter was congenitally deficient, and the left kidney was saccular and filled with a caseous substance. In these and similar cases, however, the kidney is functionally absent and from the surgical standpoint useless.

Two ureteral orifices may be present and yet one kidney may be absent, or quite rudimentary. The pelvis of the ureter in these cases is also small or absent altogether. The condition, if suspected, might be diagnosed by passing with a catheterising cystoscope an ureteral catheter (which is opaque to X-rays) as far as the renal pelvis. The renal pelvis may then be injected with collargol 10 per cent. in water, and the patient then examined with the X-rays. This should be done on both sides, as the condition is sometimes bilateral. Such a case occurred last year in a female subject in the Anatomy Department of King's College, London. Both kidneys and ureters were atrophied, as were also the ureters, ovaries, and Fallopian tubes. The main blood-vessels of the abdomen and pelvis were also about half their normal size. The method of injecting with collargol would be useful also in the diagnosis of "horse-shoe" and other forms of fused kidney. In these cases the kidney and pelves of the ureters are usually situated near the middle line, and are lower in position than the normal kidney.

Should an operation for nephrectomy have already been commenced, without a previous cystoscopic and X-ray examination having been made, and it is found that the kidney (apart from the disease) is nearly double the normal size, and that there is more than one renal artery and vein, these conditions should lead one to suspect the absence of the opposite kidney, and the operation should not be completed without first having ascertained that the opposite kidney is present.

Etiology.

The causation of congenital absence of one kidney and its ureter is, like that of other congenital abnormalities, obscure, but it is probable that the defect originates in an arrest of development of the distal end of the Wolffian duct, and of its union with that part of the cloaca from which the urogenital sinus is derived. The normal outgrowth of the renal diverticulum is therefore checked. The mesonephros, the genital gland, and the upper or proximal end of the Wolffian duct, if formed, subsequently atrophy. This atrophy in the male subject is probably due in part, at least, to there being no outlet for the escape of the testicular secretion.

The frequent cystic condition of the atrophic forms of kidney may be explained by a faulty union, or a complete failure in the union of the tubules of the metanephric blastema with the excretory tubules of the renal diverticulum.

The kidney is congenitally absent on the left side about twice as frequently as on the right. In twenty cases, including my own, the left kidney was absent in fourteen, the right in six. This may possibly be due to the fact that the umbilical cord is most frequently to the right side of the tail in young embryos of from 4–10 mm. length. It is during this period that the Wolffian duct first penetrates the wall of the cloaca and the renal diverticulum grows out from its lower end. Now, as the cloaca will be pulled over to the right with the umbilical cord, it will be farther away from the growing lower end of the Wolffian duct on the left than on the right side. This may account for greater frequency in the failure to unite with the cloaca on the left than on the right side.

Summary.

In conclusion, I will give a brief summary of the more important points to be learnt from a consideration of these cases.

1. The enlargement of the remaining kidney, when one is congenitally absent, is a pure hypertrophy.

2. The importance of cystoscopic and X-ray examinations, and of noting the presence of other congenital defects, in all cases in which nephrectomy is contemplated.

3. Congenital absence of the kidney and ureter is in all probability due to an arrest in the development of the distal end of the Wolffian duct, and to a failure in its union with the cloaca.

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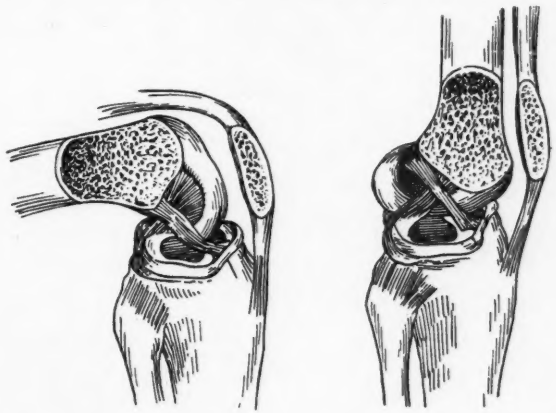
ON THE PHYSIOLOGY OF THE CRUCIAL LIGAMENTS AND SEMILUNAR CARTILAGES OF THE KNEE-JOINT, WITH A SUGGESTION OF THE ORIGIN OF SOME INSTANCES OF HÆMARTHRUS AND LOOSE BODIES.

By EDRED M. CORNER, M.C. (Cantab.), *St Thomas's Hospital, London.*

THE exact functions of the crucial ligaments of the knee-joint as given in the text-books of anatomy are abstruse and complicated. Within the last two years, whilst exploring a number of knee-joints surgically, it has occurred to me that the usually given explanation of the functions of these



A. B.

FIG. 1. — After *Quain's Anatomy*, to illustrate the generally accepted physiology of the crucial ligaments. A. The *anterior* tight in extension, slack in flexion. B. The *posterior* tight in flexion, slack in extension.

ligaments is wrong, and that the misleading statements have been copied from book to book, with little or no thought on the part of the authors. Consequently it appeared that there was a useful purpose served in making this brief contribution.

Shortly, the text-book statements which are accepted may be summed up as follows:—

The *anterior crucial ligament* is tight in extension of the knee, and slack in flexion.

The *posterior crucial ligament* is tight in flexion of the knee, and slack in extension.

This is wrong, as can be seen whenever a knee-joint is thoroughly opened and explored, either in the operating theatre or in the dead-house. I had better explain that the joint is best opened for examination by a longitudinal incision over the front of the patella; the ligamentum patellæ, the patella, and the rectus femoris muscle are thus split in the

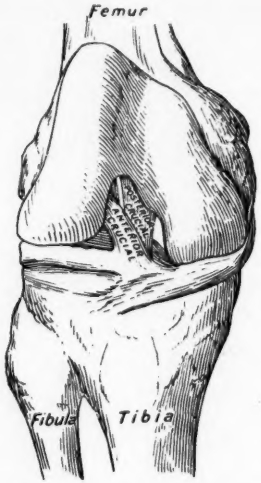


FIG. 2.—After *Gray's Anatomy*, but showing, in spite of the accepted teaching, the anterior crucial ligament tight in flexion of the knee.

same line (see fig. 3, A, B, and C). The two halves of the patella are held aside with hooks, so that by means of flexing the joint full inspection of all parts can be obtained. I had the honour of showing this to the American Medical Association, which met in Atlantic City this year (1914). This is the main source of evidence upon which I base my contentions as to the true physiology of the crucial ligaments of the knee-joint.

The functions of these ligaments are :—

(1) *Both* are taut in full extension and full flexion.

(2) *Both* are slack in semiflexion.

The slackness in semiflexion of the knee allows the semilunar cartilages to be injured by rotation movements of the joint in the semiflexed position.

Miners who work in a crouching position, with flexed knees, are well known to be particularly prone to injure their semilunar cartilages. The displaced cartilage is further displaced, permanently displaced, torn, or fractured by any subsequent movement of extension of the joint. Thus we see that the uses of the semilunar cartilages in adapting the joint-surfaces of the femur and tibia are most valuable in positions of semiflexion of the joint, *i.e.* when the crucial ligaments are most slack, particularly in rotation movements of the joint. In fact, it becomes obvious that the crucial ligaments and the semilunar cartilages form part of a mechanism which gives stability to the knee in different positions of the joint. They are interdependent structures, whose liability to injury largely depends on

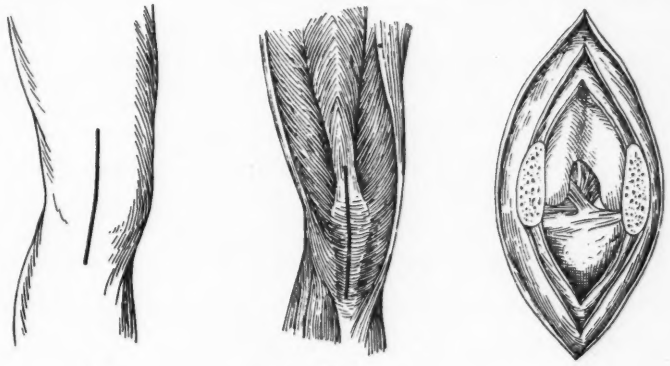


FIG. 3.—Illustrating the method of exploring the joint.
A, the skin incision; B, the line of division of the rectus, patella, and ligament; C, the joint opened and flexed.

the fact that, though we have assumed an erect attitude with straight knees and taut ligaments, from time to time we crouch with half-bent knees and slack ligaments. Then is the time for injury.

(3) *Both* ligaments resist rotation movements, particularly the anterior crucial ligament in the external rotation of the tibia. This is well seen in the external rotation of the foot and leg when the crucial ligaments have been destroyed by injury or disease.

The physiology of the crucial ligaments and the semilunar cartilages is exaggerated and perhaps parodied in the injuries of these structures. My knowledge of their physiology was drawn from these sources, and was so definite and decided that I have had the temerity to record my conclusions.

It should be added that the crucial ligaments are likely to play a very

much greater part in the surgery of the knee-joints than they do at present. For instance, this illustration (fig. 4) serves to show how any strain on the lateral ligaments, most frequently internal, is taken up by the crucial ligaments. Their ability to withstand the strain decides whether the complete or partial rupture of the crucial ligaments will occur.

I would note another anatomical fact of great clinical importance. The synovial membrane on the front of the joint, where the amplitude of movement is greater, is more loosely attached to the underlying parts than it is at the posterior parts of the joint, where the amplitude of movement is less. The tight attachment is most noticeable in the reflexion

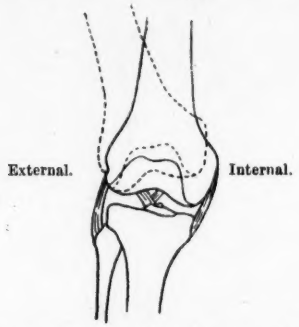


Fig. 4.—Illustrating how the crucial ligaments, in the centre of the joint, take up the strain put on all ligaments on the periphery of the joint.

of the synovial membrane over the crucial ligaments. If reference is made to the last figure (fig. 4) it will be seen that the strain of practically all injuries to the joint is taken up by the crucial ligaments. In consequence the ligaments, particularly the anterior, I believe, are often stretched. These ligaments are an arm of fibrous tissue in a sleeve of tightly applied synovial membrane. Were the stretching capabilities of fibrous tissue and synovial membrane the same, all would be well. But they are different, and with the more severe strains the synovial membrane splits. From these ruptures comes the blood so commonly found in effusions into the knee consequent on an injury. Further, in the healing of these lacerations layers of fibrin may be detached by movements of the joint. Many such detached fibrinous bodies will be removed by leucocytes. A few will remain behind to form the nucleus of loose bodies in the joint. Their subsequent trituration in the joint, produced by the movements, leads to

changes in them which completely obscure their origin. For years loose bodies may give rise to few or no symptoms. Then they get nipped in between the femur and the tibia, perhaps broken. After this they may settle and become attached to the synovial membrane. Their attachment to the synovial membrane is a reversal of the ordinarily accepted doctrine that some of these bodies arise by becoming detached from fringes of the synovial membrane.

THE EPIPHYSIS OF THE HEAD OF THE FEMUR.

By Thomas Walmsley, M.B., *Demonstrator of Anatomy, Glasgow University.*

So far as the writer is aware, there is on record no detailed description of the epiphysis of the head of the femur—that separate centre of ossification in the continuity of the cartilaginous "Anlage"—apart from the usual statement that the margin of the articular cartilage of the head represents the position of the epiphyseal cartilage.

At birth, as is well known, the femur is ossifying in its diaphyseal portion, the lower epiphyseal centre is usually present, but the whole of the upper extremity of the femur is as yet one undivided mass of cartilage —the tri-epiphyseal cartilage (fig. 1). In this upper cartilage appear

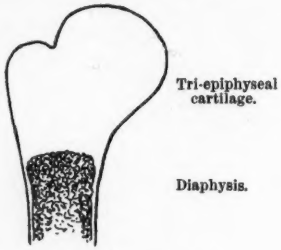


Fig. 1.—The proximal extremity of the femur, at birth.

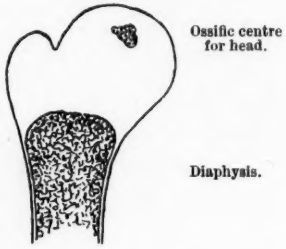


Fig. 2.—The ossific centre for the epiphysis of the head, at eleven months.

ossific centres, for the head towards the end of the first year, and subsequently for the trochanters. In the consideration of that centre which ossifies as the articular portion of the head of the femur, there will fall for study the shape and change of shape of the epiphysis, the position and change of position of the epiphyseal cartilage, the effects of these changes in addition to their causation, and of this especial epiphysis its blood supply.

The ossific centre for the head, often surrounded by a number of small osseous granules, appears then a little earlier or a little later towards the end of the first year,[1] and the position of its earliest occurrence is above and medial to the centre point of the whole head (fig. 2). After the

[1] This centre may appear at the tenth month, or may be absent at the thirteenth month.

appearance of this ossific centre, the head, yet mainly cartilaginous, is still connected with the great trochanter by a thick mass of epiphyseal cartilage; but after differentiation of the trochanter as a separate ossification, these two epiphyses are gradually separated from one another by the growing diaphyseal neck, and subsequently increase in size quite independently of one another. By the end of the fourth year nearly the whole of the epiphysis of the head is osseous, the cartilage now consisting only of the thin dentate epiphyseal cartilage separating the head from the neck. At seventeen years the epiphysis is fully ossified, and finally joins the diaphysis about nineteen to twenty years, though a line of separation often persists at the circumference, especially at the lower part, even with

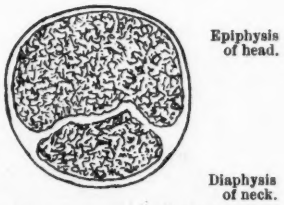


FIG. 3.—Section through head of femur, medial and parallel to the articular margin, at twelve years.

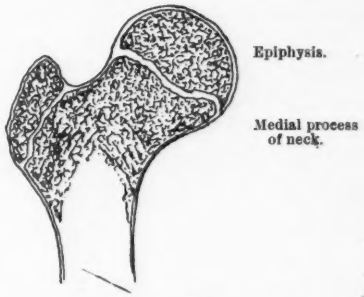


FIG. 4.—Vertical section of femur, at twelve years.

firm osseous union at the centre. On section, a line of dense bone persists for some years, indicating the line of cartilaginous union. Taking, however, a section through the head parallel to the articular margin but medially distant about one centimetre, such as is represented in fig. 3, at about twelve years of age, there is clearly shown the large part taken by the diaphyseal neck in the formation of the central core of the head, and the peculiarity of the manner in which it does so. This peculiarity consists of the greater proportional representation of the diaphysis at the under part of the head as compared with the upper. An examination of the upper surface of the diaphysis is explanatory of this peculiarity, for on reference to fig. 4 it is clearly shown that the inner end of the neck projects above the general plane of the rest of this diaphyseal surface. At this age (twelve years) the diaphysis of the neck forms a central core down over which the articular surface of the epiphyseal head extends: not in a regular fashion, however, but yet so as to embrace the upper end of

the neck in a circularly complete manner. While the under surface of the epiphysis of the head is thus concave in all directions, it is most deeply excavated at its application to the medial process of the neck, and the extension of the epiphysis over the diaphysis is in this situation the most limited. (Macalister has already pointed out how the thin irregular rim from the head extends outwards over the upper part of the neck, and assists in the transmission of weight from the head above to the calcar femorale of the neck below.) From a morphological point of view, however, it is more important to recognise that the lower aspect of the epiphyseal rim extends to the least extent over the diaphyseal neck, that it is the thinnest part of the whole epiphysis, and that it is the last portion to become osseous. It will also be noted, and more especially at the period immediately previous to the bony union of the epiphysis with the diaphysis,

Fig. 5.—Head of femur of seal—diagrammatic.

that both ossifying surfaces are irregular; and the irregularities are so arranged and of such a shape, that small hemispherical nodosities of the upper surface of the neck are occupying small concavities of the under surface of the head.

On tracing the ontogeny of this epiphysis, the diaphyseal spur at the medial extremity of the neck will be found to be best developed towards the age of puberty; and though in the process of formation it may be recognised at an earlier period of life, till the age of four years it is certainly non-existent. The advantage gained by such a process is in preventing any undue tendency to luxation of the epiphysis, a tendency, as may be shown, at its greatest degree of mechanical possibility when this natural means of prevention arrives at its maximum of development. A comparison with the femur of the seal is instructive not only as regards the phylogeny of the medial process of the neck, but also in assisting to a decision of the morphology of the ligamentum teres of the hip-joint. In the Ross seal the articular head of the femur is incomplete, so that the medial process of the neck is entirely a superficial structure (1) (fig. 5). That the ligamentum teres is isolated by the development of the head of the femur as a wing expansion on each side of the ligament, with subsequent

fusion of the wings under the ligament at the lower part of the head, as stated by Keith, seems strongly substantiated by the mode of development of the epiphysis.

The axis of the head and neck of the femur in the fœtus is, in respect to that of the shaft, vertical, or perhaps spiral, so that the angles of inclination and declination are both of large size (150° and 45° respectively), and till the end of the first year there is little alteration of the femur in these respects. The epiphyseal cartilage will thus be found horizontal in position even as late as the third year. After this period, however, the cartilage comes more and more to occupy an oblique position, so that before its final absorption it slopes downwards and inwards at an angle of at least 30°. As causative of this change there is the interaction of the developmental and mechanical forces. For, on to the almost vertically growing femoral neck of the young subject there is transmitted, more on its medial than on its lateral side, a shearing force acting vertically, tending to produce an angle between the two components of the femur, and as a result there is, not a bending of the cartilaginous tissue of the head or of the osseous tissue of the neck, but a change in the plane of the epiphyseal cartilage. This cartilage is horizontal in the young bone, and to assume the adult obliquity there is, as it were, a greater amount of growth at its outer end than at its inner end. As a direct result of this change in position there are two alterations in the form of the femur. Firstly there is the progressive decrease in the angle of inclination of the neck, and secondly there is the alteration in position of the axis of the head. The head, transmitting the same vertical force as before, becomes "tilted over" to the oblique adult position, so that at that period of life, ten to fourteen years, while the cartilage is in the adult obliquity yet still cartilaginous, there is the greatest tendency to the occurrence of the condition of "traumatic slipped epiphysis."

The blood-vessels which enter the hip-joint by passing under the transverse ligament of the acetabulum have been defined by all observers as arising from the external branch of the a. obturator and from the medial circumflex branch of the a. profunda femoris. The work of Ssawwin (2) is the most detailed. He demonstrated by means of very fluid injections that the obturator branch anastomosed with that of the medial circumflex to form two main vessels, one, the a. acetabuli, constant, which formed a rich vascular network in the Haversian fat, the other not at all constant, the a. ligamenti teretis, which ran through the ligamentum teres to the head of the femur. In some cases he found no vessel in the round ligament at all, in most a fairly well-marked channel, and in a few specimens a double artery.

The method adopted by the writer was one of differential injection with very fluid media, the posterior division of the internal iliac artery being injected with one colouring matter, and the rest of the body with a differently coloured preparation. By this means it was determined that running underneath the transverse acetabular ligament there is a large branch from the external division of the a. obturator, and a smaller branch from the internal circumflex artery. These two vessels united in the floor of the acetabulum and formed a network, exactly as described by Ssawwin, and from this network a small branch proceeded to the ligamentum teres.

Many authors hold, of course, that this is the sole function of the ligamentum teres, to lead vessels to the head of the femur.[1] After a most careful inquiry Welcher (3) came to opposite conclusions. On an analysis of 30 cases he found that

in 9, there were no vascular markings on the floor of the teres fossa;
in 11, only one or two small pits;
in 8, there were three to six foramina;
in 1 ten, and in 1 twenty-five small openings.

Hyrtl also upholds the view that the ligament does not convey blood-vessels to the head of the femur, and claims to have proved that at the femoral extremity of the ligament the arterial vessel forms a capillary loop and runs back as the vein. For the present work about 100 round ligaments were examined for the contained vessel by means of a hand lens, yet a vessel of any size was never found; therefore it was concluded that not only is this vessel not the sole supply, but that it can convey only a very trifling amount of blood to the head of the bone. On minute examination of the "differentiated" specimen numerous vessels were found ascending to the head from the articular margin, but not the slightest evidence of any vascular channel from the ligamentum teres into the neighbouring bone could be determined; that is, in the adult at least, the blood-vessels of the ligament are not destined for the supply of the head of the femur. In support of this anatomical fact there is the finding of pathology, first in regard to dislocation of the hip, and secondly in fracture of the neck of the femur. For the full development of the former condition there must be of necessity a complete rupture of the round ligament, yet after reduction of the dislocation it is never held that the head of the femur is defective in nutrition. A considerable amount of detailed work is available in regard to fracture of the neck of the femur, and here the consensus of reliable opinion is that the condition of the ligament is absolutely immaterial, the rupture or non-rupture of the synovial and

[1] Henle and Sappy both held this view.

fibrous connexions between the neck and the head with the contained vessels determining the future state of the head.

It is in the child, however, it is by some writers held, that the ligamentum teres as a means of leading vessels to the femoral head is in the fullest degree active, and after that period the blood supply is derived from the blood-vessels of the diaphysis at the articular margin (Lange). Against this view there are the very dogmatic statements of Fick and of Welcher. The former (4) definitely states: "In the young subject the blood supply is not through the round ligament, but through the vessels which enter the large foramina at the articular margin of the head"; while the latter is equally certain of this view in the determined absence of vascular foramina in the teres fossa of the embryo and of young children.

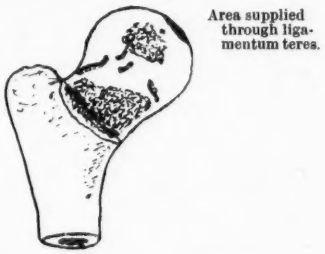


FIG. 6.—Blood supply of centre of ossification, at two years of age.

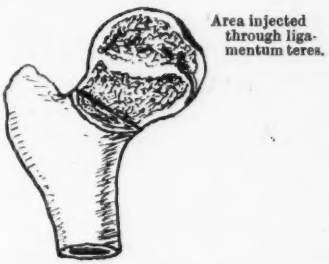


FIG. 7.—Blood-vessels of head, at six years of age.

For the present work two male children, aged two years and six years respectively, were prepared by the differential injection method already described. In the child of two years—that is, at a period when the ossification of the head is not to any extent advanced—the blood-vessels which passed to the osseous nucleus were derived in no part from those of the ligamentum teres, but entirely from vessels entering the neck of the femur at the articular margin of the head. These vessels are distinctly seen in their course to the centre of ossification, lying in the lower part of the cartilage of the head, but a small area of the superficial cartilage above this centre and in the immediate proximity of the attachment of the ligamentum teres did seem to be vascularised from the a. ligamentum teretis (fig. 6). The specimen obtained from the child of six years (fig. 7) also gave emphatic evidence that for purposes of ossification the blood supply is obtained, not from the vessels of the ligamentum teres, but from those which enter at the articular margin of the head and pass thence proximal to the epiphyseal plate to ramify in the osseous substance of the

head. And when in addition it is determined in those cases of congenital dislocation of the hip that the head of the femur undergoes no especial atrophy in the absence of the ligamentum teres, it may no longer be held that "the round ligament conveys a blood supply to the head of the femur."

As regards the foramina in the floor of the teres fossa, the following alternative view as to their causation is advanced. From a detailed examination of these foramina there is made evident not only the inconstancy in number as described by Welcher, but that the sectional area of the average number is out of all proportion to that which could possibly result from a subdivision of the a. ligamenti teretis: that is, all of these openings could not possibly be intended as vascular channels. Now, from a study of the method of attachment of the ligamentum teres to the head of the femur in the fœtus and in the adult, it may be shown that, while the marginal parts of this ligament may become continuous with the superficial layers of the articular cartilage, the central parts are in direct continuity first with the cartilaginous and subsequently with the osseous substance of the head. And the foramina, found only in the adult, represent such channels of communication.

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PROFESSOR OF ANATOMY IN THE UNIVERSITY OF EDINBURGH

THIS VOLUME

IS DEDICATED

AS A SMALL TOKEN OF ESTEEM AND

SINCERE PERSONAL REGARD BY HIS

FORMER PUPIL AND ASSISTANT.

EXTRACT FROM PREFACE.

IN undertaking a work upon Applied Anatomy my object has been to provide an account of the regional anatomy of the human body in its more important applications to Medicine and Surgery. It has been my conviction for many years that the subject of anatomy might with advantage be taught to students of medicine more from the applied standpoint and less as an abstract science. Some years ago, at the instigation of Professor Cunningham, a course of lectures in Applied Anatomy was made obligatory in the Medical School of Trinity College, and has been productive of the most gratifying results. Were anatomical teaching conducted more generally on these lines, it would, I have no doubt, help to bridge over the wide gap which separates the dissecting room from the surgical theatre, and render the transition from the one to the other less abrupt; the subject would possess more attraction for the student, it would be more easily remembered, and certainly more useful.

Although I have endeavoured to treat the subject of Applied Anatomy in a general way, yet, in the main, the book is surgical; indeed, in some respects its scope might have been more correctly expressed by giving it the title "Surgery from the Anatomical Standpoint."

The general plan adopted in the arrangement of the text is one which I have found by experience most popular with students in the lecture theatre. Each region is introduced by a concise account of its topographical anatomy, developmental details being supplied where necessary, and subsequently the more important lessons—medical, surgical, and pathological—which are to be derived from it are presented for consideration.

To the Surgeon an accurate knowledge of anatomy is not only desirable—it is a matter of absolute necessity. Such knowledge favours correct diagnosis in many cases by affording valuable aid in the interpretation of symptoms; it ensures clean cutting and neat operating, instead of clumsy manipulations and harmful damage of tissues. It enables the Surgeon also to carry out the principles of conservative surgery in the fullest sense of the term; it puts him in a position to plan his incisions to the best advantage, and to avoid unnecessary injury of those parts which it should be his object to leave intact.

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Probably at no period in history has anatomy been so closely bound up with surgery as at the present day. When performed under strictly aseptic conditions, operations of great magnitude are now possible. In many instances these partake largely of the nature of elaborate and carefully planned dissections; particularly does this apply to the eradication of malignant disease in the different parts of the body—breast, rectum, etc. etc. The operative surgery of the tympanic region, as carried out in recent years, has resolved itself largely into an exercise in the intricate anatomy of the temporal bone and its surroundings.

In the production of this work it has been my aim to provide a series of illustrations which should possess a thoroughly practical value combined with accuracy. With few exceptions, the sources of which are fully acknowledged in the text, the figures are original, and have been drawn from specially prepared dissections and from specimens in the Medical School of Trinity College, by Mr James T. Murray, of Edinburgh. To this highly accomplished artist I am deeply indebted for the zealous and painstaking care which he has bestowed upon his difficult task. In order to enhance the value of the dissections which are interspersed throughout the book, each figure is provided with a concise explanatory note in which attention is directed to the particular points which the dissection is meant to represent.

In the preparation of specimens for dissection I have made extensive use of formalin injection, which has proved such a valuable reagent for hardening the various tissues *in situ*. In determining the topography of the abdominal and thoracic viscera this reagent is of special value, as it provides an accurate means of determining the shape and the respective areas of contact of the viscera at the time of death.

While the book, as it stands, is mainly intended for senior students, who have just completed their courses of dissection, and whose memories are stored with general anatomical details, it has been my desire that it should possess a real value for the specialist and for the general practitioner, and that it may enable those whose knowledge of anatomy has grown somewhat dim to refresh their memories without any excessive expenditure of time and labour. To those also who are engaged in preparation for the higher examinations in medicine and surgery I trust it may prove a useful help.

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In controlling hæmorrhage in operations which involve the scalp, advantage is sometimes taken of the upward course of the arteries and their close proximity to the bone, by encircling the head with an elastic band at the level of the supra-orbital margins in front and below the external occipital protuberance behind; this is a useful precaution to adopt in the removal of large scalp tumours such as pachydermatoceles or nævoid growths. A peculiar form of vascular growth called *cirsoid aneurysm*, or aneurysm by anastomosis, is occasionally observed in connec-

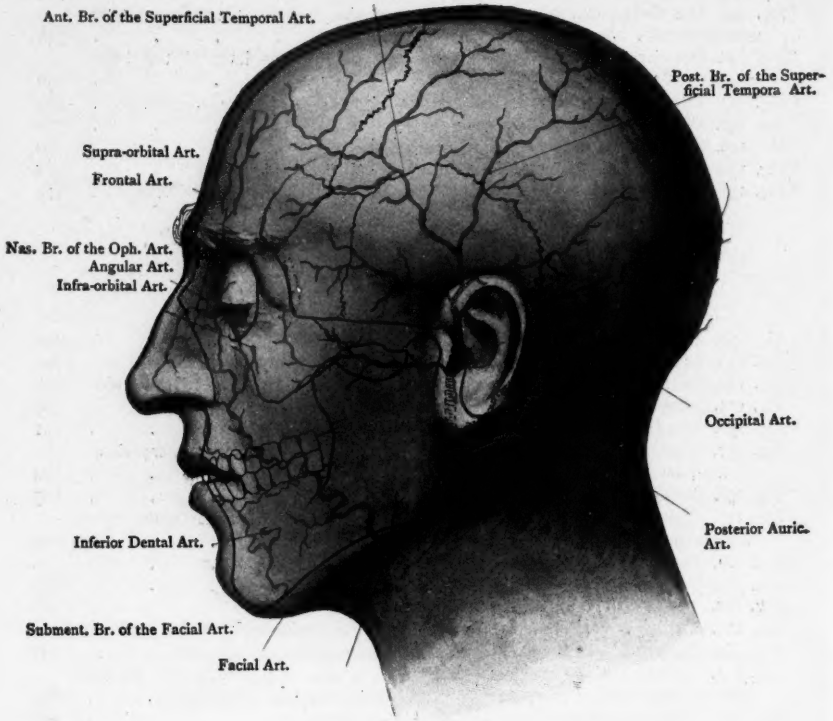

FIG. 2.—Topographical representation of the arteries of the scalp and face.

tion with the superficial temporal artery, less frequently with the occipital. It consists of a number of large, tortuous, and pulsating vessels forming an irregularly circumscribed swelling of a bluish red colour beneath the skin. Ligature of the superficial temporal or occipital artery, as the case may be, has been performed in these cases as a curative measure, but in view of the very free collateral anastomoses it could hardly be expected to have the desired effect. Ligature of both external carotids would hold out greater hope of success, but even after this the vessels derived from the internal carotid artery through its ophthalmic branch (*frontal and supra-orbital*) may render this mode of treatment futile.

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with the retina. The ciliary vessels are mainly distributed throughout the uveal tract, and must now be reviewed in detail.

The Ciliary Arteries consist of three main groups, which are arranged as follows (fig. 41):—(1) *The Short Posterior Ciliary Arteries.*—These are derived from the ophthalmic artery, or from some of its main branches; they run forwards to the eyeball by the side of the optic nerve, and having subdivided so as to form a large number of branches, about twenty on an average, they pierce the sclerotic and enter the chorioid, within which their smaller subdivisions anastomose freely in the chorio-capillaris, and are largely reinforced by recurrent branches from the ciliary body. Some branches derived from the posterior ciliary arteries pierce the ensheathing membranes of the optic nerve immediately before it traverses the sclerotic, and form anastomoses with the central artery of the retina. (2) *The Long Posterior Ciliary Arteries*, two in number, run forwards with the short vessels, one upon the inner, the other upon the outer side of the eyeball, and pierce the sclerotic a little behind its equator; they are continued onwards in the loose tissue of the membrana suprachoriidea to the ciliary muscle, where they enter into communication with (3) the *Anterior Ciliary Arteries.* These are minute vessels derived from the arteries which supply the recti muscles. They travel forwards along the recti tendons to the sclerotic, two arteries usually with each muscle. Having given some twigs to the conjunctiva and to the extreme

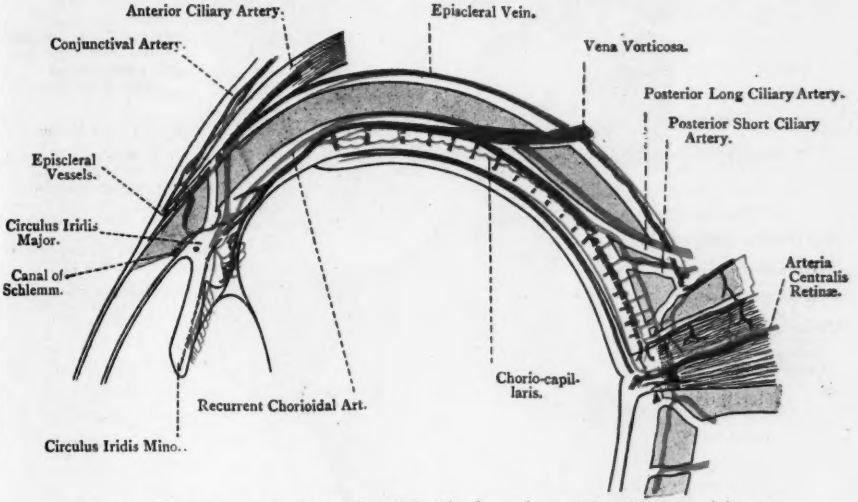

FIG. 41.—Diagrammatic representation of the blood-vessels supplying the globe of the eye (after Leber).

periphery of the cornea, they pierce the sclerotic near the corneo-scleral margin. The two latter groups anastomose freely with each other, and form a vascular ring in front of the ciliary muscle, called the *circulus iridis major.* Branches of minute size which proceed from this arterial circle supply the ciliary processes; some pass backwards into the chorio-capillaris, and others enter the iris, within which they form another vascular ring, the *circulus iridis minor*, near the pupillary aperture.

The Veins of the Eyeball.—The large arborescent veins belonging to the outer vascular layer of the chorioid, viz., *the venæ vorticosæ*, four or five in number, pierce the sclerotic in the line of the equator of the globe, and carry away the greater part of the venous blood from the eyeball.

A remarkable venous sinus—*the Canal of Schlemm*—is found in the deeper layers of the sclerotic, close to the cornea and the periphery of the iris. By its inner aspect it comes into close relationship with the spaces of Fontana, which are situated between the networks of the ligamentum pectinatum (see Cornea), and in direct communication with the anterior chamber at the irido-corneal angle. The blood contained within this sinus is drained away by the anterior ciliary veins, which pursue the same course as the anterior ciliary arteries and drain away the blood from the anterior part of the conjunctiva, from the periphery of the cornea, and from the sclerotic. They form extremely fine episcleral networks, which extend for 5 or 6 mm. from the margin of the cornea; they end partly in the venæ vorticosæ and partly in the veins of the orbital cavity.

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area. In the hands of Ballance and others this procedure has been attended with a very large measure of success.

Abscess in the Temporal Lobe of the Brain.—An otitic abscess

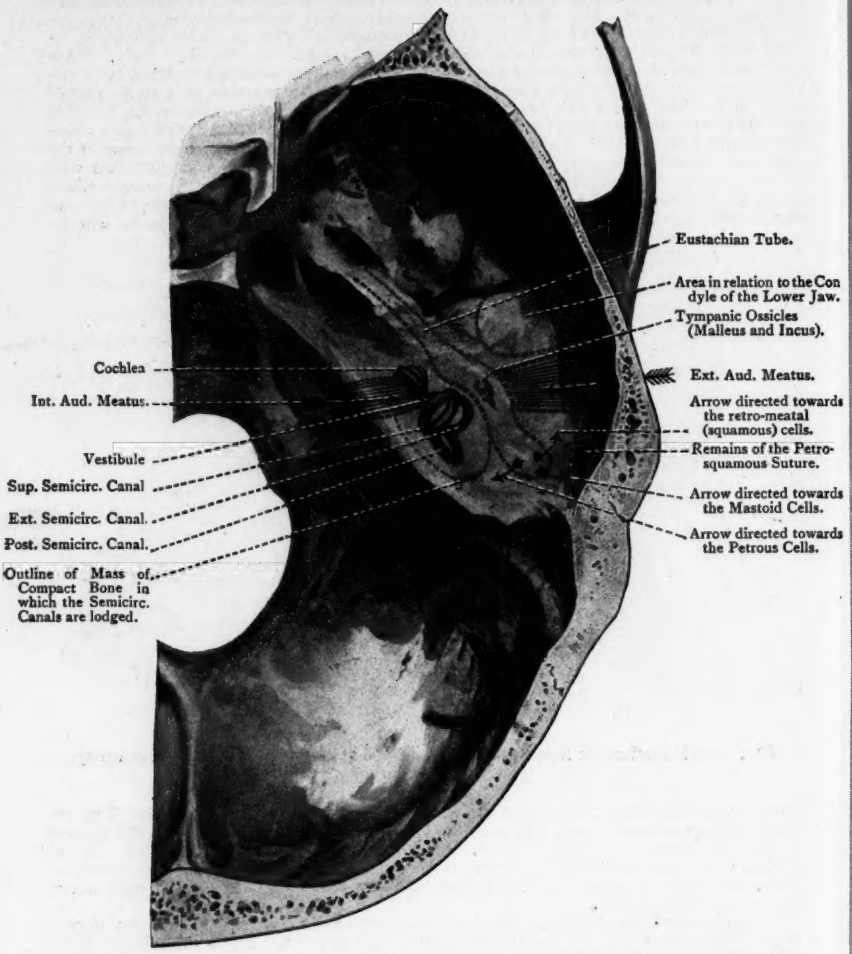
Eustachian Tube.
Area in relation to the Condyle of the Lower Jaw.
Tympanic Ossicles (Malleus and Incus).
Cochlea
Ext. Aud. Meatus.
Int. Aud. Meatus.
Arrow directed towards the retro-meatal (squamous) cells.
Vestibule
Remains of the Petro-squamous Suture.
Sup. Semicirc. Canal
Arrow directed towards the Mastoid Cells.
Ext. Semicirc. Canal.
Post. Semicirc. Canal.
Arrow directed towards the Petrous Cells.
Outline of Mass of Compact Bone in which the Semicirc. Canals are lodged.

FIG. 23.—The middle and posterior cranial fossæ in the macerated skull—actual size. In the middle fossa the outlines of the bony labyrinth, tympanum, mastoid antrum, Eustachian tube, and the two auditory meatuses are projected on the surface. This view is instructive from the standpoint of the operative surgery of the middle ear. Were the course of the facial nerve indicated here, it would be seen extending along the internal auditory meatus, then passing forwards slightly between the cochlea and the vestibule before disappearing from view by turning downwards in front and to the outer side of the external semicircular canal. The parts outlined in blue have been drawn from a skiagram of the skull here represented. The author is much indebted to Dr E. J. Watson for his valuable assistance in enabling him to determine many points in the topographical relationships of the temporal bone by means of a series of X-ray photographs.

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in the temporal lobe is usually to be found in the vicinity of the tegmen tympani, and it has been shown by Macewen and others that in the greater number of cases the infection has spread by direct continuity into the brain substance through a carious opening or membranous gap in the tympanic roof. This fact also explains how an abscess in the temporal lobe may discharge its contents into the tympanic cavity and external auditory meatus. It is always advisable, therefore, when an attempt is made to reach the abscess, that the opening in the skull should be in a position which will afford access not only to the infected focus in the temporal lobe but also to the tegmen. This object may be attained by turning down a semicircular flap above the ear and by inserting the pin of a three-quarter inch trephine one inch directly above the level of the upper border of the meatus. When the dura mater is exposed, it is divided by a limited straight incision and an exploring needle is inserted into the brain (fig. 19). If pus is discovered, the brain is incised and the abscess contents evacuated. Should it happen that no abscess is found, the bone may be snipped away down to the floor of the middle cranial fossa and inwards as far as the tegmen. The condition of the dura mater here can then be examined, and if a sinus leads through it, it may be the means of discovering the abscess.

If the search has so far yielded negative results, it would certainly be advisable to examine the condition of the lateral sinus, and even to explore the cerebellum. To carry out this procedure it is merely necessary to extend the opening in the bone backwards and downwards, bringing the sinus into view, and beyond this the dura mater of the cerebellar fossa. An existing *thrombosis in the lateral sinus* may supply the real key to the situation, but with it there may also be a leptomeningitis in the cerebellar fossa and an *abscess in the cerebellum*, a common site being its anterior and outer part. The best site for the exploration of the cerebellum is below the horizontal and behind the vertical or descending stage of the lateral sinus, or at the centre of a line connecting the tip of the mastoid process with the external occipital protuberance.

With *thrombosis of the lateral sinus* there may be an extensive area of pachymeningitis, and perhaps an extradural abscess in the cerebellar fossa, extending from behind the groove for the sinus forwards to the posterior surface of the petrous bone. This will require the removal of the greater part of the mastoid bone, care being taken not to encroach upon the posterior semicircular canal in front, unless the labyrinth be infected at the same time.

As there is usually very great difficulty, if not impossibility, in ascertaining with precision in any given case whether a patient with purulent otitis media who presents symptoms of intracranial inflammation suffers from an abscess in the temporal lobe or in the cerebellum or whether the case is one of lateral sinus thrombosis, many surgeons prefer not to delay operation until more definite localising symptoms appear, but to proceed at once to open up the antrum and tympanic cavity in the manner just described, trying at the same time to find at what point the infection has travelled intracranially. In this way the lateral sinus is exposed and its surroundings examined; if this prove unsuccessful, the tegmen tympani is explored and search made for a sinus leading upwards through it. It is by following out a policy such

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deep aspect of the skin by means of fibrous septa, which were designated by Sir Astley Cooper the *suspensory ligaments of the breast.*

The Lymphatics of the Breast.—Both the acini and the ducts of the gland are surrounded by a network of lymphatic vessels (*peri-ductal and peri-acinous lymphatics*), which communicate freely with the lymph vessels which ramify in the interglandular tissue, separating the gland lobules (*interlobar lymphatics*). These again communicate with the lymphatics which lie in the subcutaneous tissue, and with those which run in the retromammary tissue and traverse the pectoral fascia. The subcutaneous or supramammary lymphatics also bring the vessels of the gland into free communication with the networks in the skin, the 'suspensory ligaments' serving as conducting paths for the vessels which pass to and fro. Efferent vessels lead away from the peripheral margin of the gland to the axillary glands, the majority passing to the anterior or pectoral group, and thence to the central and the deep glands which are arranged along the anterior and inner aspects of the axillary vessels. Some of the efferent vessels from the gland, however, pass directly to this deep group without being intercepted on the way. Certain of the lymphatics from the inner part of the mamma betake themselves to the anterior

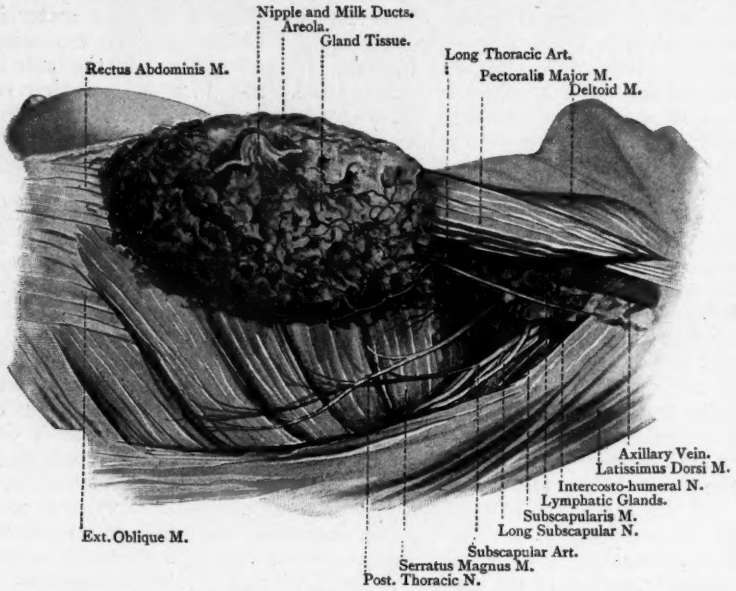

FIG. 74.—Dissection of the mammary gland and axillary outlet in a subject in the sixth month of pregnancy. Note that the basal aspect of the gland is related to the pectoralis major muscle above, to the serratus magnus externally, to the origins of the rectus abdominis and external oblique muscles below. The nipple has been retained *in situ*, and the large milk ducts are seen entering its deep aspect. Observe how the upper and outer extremity of the gland comes into close proximity with the axillary space. Some lymphatic glands and fatty tissue conceal the large vessels and nerves; the axillary vein, however, is seen at the outer angle of the space. Compare this figure with No. 71. This dissection is instructive in connection with cancer of the breast and its surgical treatment.

mediastinal glands which are situated alongside the internal mammary vessels (fig. 62). A few of the lymphatics which leave the gland pass to the infraclavicular group which is situated in the pectoral region, between the deltoid and pectoralis major muscles, and alongside the termination of the cephalic vein. The lymphatic systems of the two mammary glands appear to communicate by means of certain vessels which cross the middle line.

Examination of the Breast.—The free mobility of the normal mammary gland is one of its most important characteristics; the facility, however, with which it slips away from beneath the fingers is apt to

gone a certain degree of twisting around a vertical axis, as the result of which its right side comes to occupy an anterior position and its left to be directed posteriorly (fig. 103). When examined in the body after death, a procedure which is much facilitated if the tissues have been previously hardened by means of intravascular injections of formalin solution, the heart presents an outline which is roughly pyramidal. It has three well defined surfaces, viz., an anterior or costo-sternal, an inferior or diaphragmatic, and a posterior or basal; these are separated

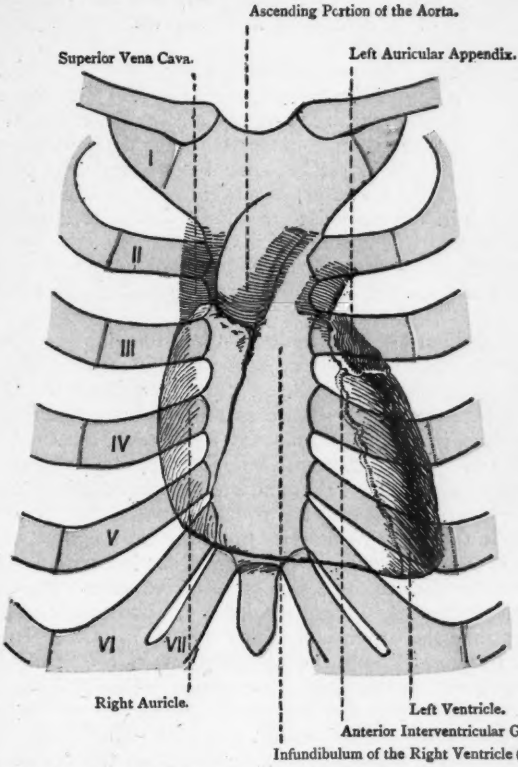

FIG. 103.—The heart in its relationships to the front wall of the chest—formalin preparation.

from each other by well defined borders, viz., the right or auricular border, the antero-inferior border or margo acutus, which is formed almost entirely by the right ventricle, the left border or margo obtusus which is formed by the left ventricle—it meets the margo acutus at the apex—and the posterior border which is interposed between the diaphragmatic and the posterior or basal surfaces.

The anterior surface of the Heart (fig. 103) looks upwards, forwards, and to the left, and is convex in shape. It is bounded below by the margo acutus, to the left by the margo obtusus, and to the right by

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of the rectum has been completed, the flaps are restored to their normal position. The advantages claimed for this method are, that there is but slight mutilation of the pelvic structures, and that as the posterior attachments of the levatores ani and coccygei muscles are preserved, there is no loss of support to the pelvic viscera, and no nerves of importance are divided. In spite of these advantages this method of gaining access to the rectum is not held much in favour at the present day.

Parasacral Incision.—Without removing part of the sacrum some operators have succeeded in getting sufficiently free access to the field of operation by means of a parasacral incision; the coccyx, however, is usually removed.

2. **Removal of the Disease.**—Having considered the various modes of approach to the rectum from behind, the *second stage* of the operation remains to be considered, viz., *the excision of the diseased part.* Should the cancerous growth be situated close to the anus it may possibly be excised through the dilated orifice, care being taken to preserve the external sphincter; this, however, is not always possible. When the cancer is situated in the ampulla or suprasphincteric segment of the rectum, it is important to determine if it is quite free of the sphincters, or if it extends within their territory (*ano-rectal cancer*). In both cases the perineal method of approach is adopted, combined perhaps with excision of the coccyx.

Ano-rectal Cancer is removed in the following manner. The rectum, already exposed from behind, is separated on each side from its lax surroundings, by the aid of the index finger, down to the level at which it is connected with the levatores ani. As the inner margins of these muscles are intimately connected with the diseased area, their partial removal will almost certainly be required, including at the same time the external sphincter. By means of strong cutting scissors, one blade of which is introduced into the wound between the levator ani and the rectum, while the other blade rests upon the skin as near as is safe to the anal orifice, the intervening bridge of tissue is divided. A similar section is made on the opposite side and carried round the entire anal margin, separating the anal canal from the surrounding parts. It now remains to continue the separation of the rectum in front. In the male this entails an incision through the posterior part of the perineal or recto-urethral triangle, above which the connections of the wall of the bowel with the recto-vesical fascia are comparatively loose and the process of separation consequently much easier. In the female the rectum is separated in front from the perineal body and from the posterior vaginal wall, with the latter of which its connection is fairly lax. At a point varying usually from two to three inches from the anus the peritoneum of the recto-vaginal or recto-vesical pouch will be encountered, and may require to be divided. As it is necessary to draw down the healthy part of the rectum above the diseased area, the dissection must be continued somewhat further. At the sides, the *lateral ligaments* of the rectum, formed by the middle hæmorrhoidal arteries and their investing tissue, must be ligatured and divided. The division of the rectal pelvic fascia behind must be free, otherwise it will offer very great resistance to the drawing down of the gut. The retrorectal fatty tissue is divided cautiously so as not to wound the larger branches of the superior

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SPECIMEN PAGE.

tapering extremities of the seminal vesicles with the vasa deferentia and the common ejaculatory ducts, which are really the continuations of these. Both ducts traverse the prostate obliquely,

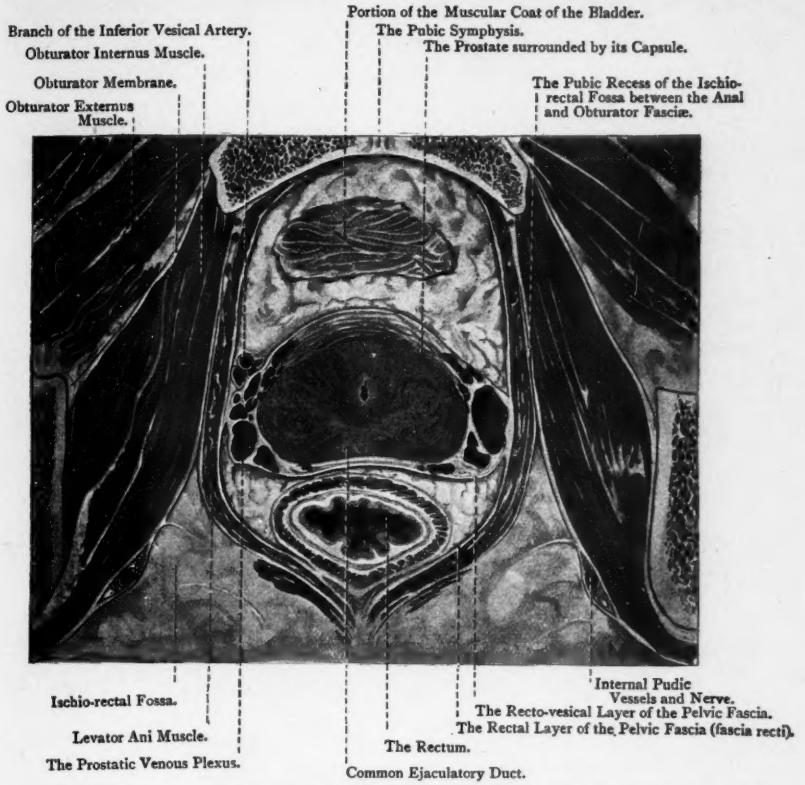
Portion of the Muscular Coat of the Bladder.
Branch of the Inferior Vesical Artery.
The Pubic Symphysis.
Obturator Internus Muscle.
The Prostate surrounded by its Capsule.
Obturator Membrane.
The Pubic Recess of the Ischio-rectal Fossa between the Anal and Obturator Fasciæ.
Obturator Externus Muscle.
Internal Pudic Vessels and Nerve.
Ischio-rectal Fossa.
The Recto-vesical Layer of the Pelvic Fascia.
The Rectal Layer of the Pelvic Fascia (fascia recti).
Levator Ani Muscle.
The Rectum.
The Prostatic Venous Plexus.
Common Ejaculatory Duct.

FIG. 146.—Horizontal section through the pelvis at the level of the basal extremity of the prostate, *i.e.* immediately beneath the bladder floor. The levatores ani muscles and the pubic bones are observed to enclose an elliptical space within which are contained the rectum, the prostate surrounded by its capsule derived from the pelvic fascia, and the veins of the vesico-prostatic plexus. In front of the prostate the section has traversed the extreme lower aspect of the bladder and has sliced off a small portion of its muscular coat. Note the manner in which the rectum is invested by loose fatty tissue and enclosed within a distinct compartment, bounded in front by the *recto-vesical*, behind by the *rectal* layer of the visceral pelvic fascia. The macroscopical appearances presented by the prostate are very instructive. The urethra is completely surrounded by unstriped muscular tissue, and behind this and quite close to the posterior border of the organ are seen the two common ejaculatory ducts cut across. Each lateral lobe is provided with a thin investing layer of connective tissue (*sheath of the prostate*) which is closely applied against its outer cortical layer of muscle from which prolongations of a septal nature travel inwards, subdividing the glandular tissue of the prostate, and become continuous with the central collection of muscle. The so-called '*middle lobe*' is that part of the prostate which intervenes between the urethra in front and the common ejaculatory ducts behind. It will be observed, however, that it can in no way be regarded as a separate part of the organ, but rather as an isthmus or commissure connecting the lateral lobes behind the urethra.

and open by minute orifices on the summit of the verumontanum (*crista urethralis*), which occupies the floor or rather the posterior wall of the prostatic urethra.

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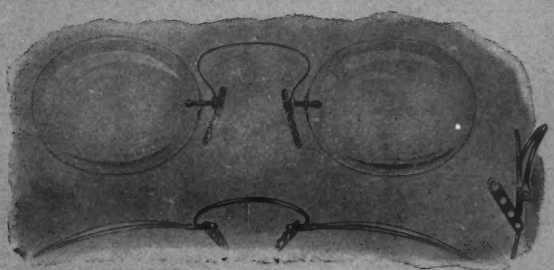

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